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COLUMBUS DISCOVERS GLASS

An account of the Autumn Meeting of the Glass Division of the American Ceramic Society, together with brief reviews of symposiums on Glass Density and Glass-to-Metal Seals.

Columbus, Ohio, was the vitreous center of America for two days, September 13-14, when 250 members of the Glass Division, American Ceramic Society, came to town and established headquarters in the Hotel Deshler-Wallick and occupied lecture rooms at Ohio State University. Program and arrangements were in the hands of R. F. Brenner, Anchor-Hocking Glass Corp., and presiding over the general meetings was O. G. Burch, Owens-Illinois Glass Co., Chairman of the Division. Professor W. E. S. Turner, of Sheffield, England, was present as a distinguished guest, bringing Mrs. Turner to America for the first time. Other English visitors were Dr. W. Maskill and Mr. J. J. Breslin.

Charles S. Pearce, General Secretary of the American Ceramic Society, brought some of his staff to assist in the registration on Friday morning, and helped in many ways in the smooth operation of a successful gathering.

The Battelle Memorial Institute and the new color laboratories of DuPont Chemical Company were open for inspection during Friday forenoon, and groups of technologists went on conducted tours.

At the business session at 11:00 on Friday, messages were read from John D. Sullivan, of Battelle; the Czechoslovakian Glass Society; the Society of Glass Technology; and from Heinrich Maurach, of the D. G. G. in Frankfort, who expressed friendly sentiments and the hope that his own society of glass technology would soon again be active.

J. S. Gregorius, Trustee, announced the proposed Frank Forrest Award, established by the Preston Laboratories of Butler, Pa., in memory of Captain Frank Forrest, killed in action, 1944. Upon its acceptance by the Board of Trustees, the plan will provide for an award of $100, to be given each year for three years to the author of the best paper on Glass Technology published during the preceding year. Details of the conditions will appear in later announcements by the Society.

The report of a special committee on program was presented by F. W. Preston, and summarized the result of informal conferences and correspondence. Certain practices in the presentation of papers in the technical programs were condemned, and certain changes in rules and procedures were suggested. The speaker ably argued that the reading of papers from manuscript or print should be prohibited; that slides should be restricted to visible—that is, legible—matter, preferably only pictures, curves, and graphs; that fewer papers should be given, with less time for presentation and more for discussion. These proposals met with much support in the lively discussion that followed, and a motion was carried to refer them favorably to the Rules Committee of the Division for action.

Other proposals, to recognize and encourage the younger members by limiting the age of chairmen and vice-chairmen to 40, to make the Fall Meeting the only technical session and use the Spring Meeting for business and policy, and to group the Glass papers in separate issues of the Journal—all these were referred to a special committee for consideration.

The two technical symposiums, held simultaneously in two of the lecture rooms at Ohio State University, were well attended, and remarkable for lively, informal discussion. Those who seal wires into glass or make glassware for the electronics industry made up an audience and debating society of more than 80 in the Chemistry Building, while the representatives of the tonnage of glass, more than 100 in number, crowded the auditorium of the Social Administration Building to hear about the measurement of density and argue the best methods of applying statistical calculations to the data obtained and using them in tank control.

Dinner on Friday evening taxed the facilities of the hotel. Introductions of our visitors from overseas and of Ross Purdy, Secretary-Emeritus and Elder Statesman of Ceramics, brought hearty applause. President J. E. Hansen called up the six newly-elected Fellows of the Society from the Glass Division, and conducted the brief and impressive induction ceremony. The newly elected

Fellows are L. G. Ghering, Preston Laboratories; J. F. Greene, Kimble Glass Company; H. H. Holscher, Owens-Illinois; K. H. Sun, Westinghouse Research Laboratories; F. V. Tooley, Owens-Corning Fibreglas Corporation; and W. Weyl, Glass Science, Inc.

The Division then listened with great interest to reports from "temporary colonels" H. H. Blau and C. J. Uhrmann, who had traveled 18,000 miles by jeep to inspect the postwar status of German glass plants. In so far as restrictions would permit, they gave a detailed picture of the destruction and disturbance, the limitations and ingenious methods, and the unusual materials and fuels employed, in unhappy Europe.

Under the auspices of the American Fellows of the Society of Glass Technology, a breakfast was held on Saturday morning, honoring Professor and Mrs. Turner. F. C. Flint, American Treasurer of the S. G. T., gave a brief history of our participation in that Society, and presented to Professor Turner a greeting scroll reciting our appreciation of his achievements, signed by more than 200 members of the Division during the previous evening. In responding, the Professor recounted his previous visits to America, and gratefully accepted the scroll as further evidence of the good will that exists between the glass technologists of England and America. F. W. Preston (of whom the English say that his speech has become Americanized, and whose American friends still detect his British accent) then recalled how he first heard of Professor Turner and his new Society in 1916, and how the term "glass technology" was coined by the Professor at that time. Dr. Preston's story follows at the end of this review.

The closing session, in Commerce Auditorium, O.S.U., brought John T. Ogden and F. W. Preston, who, as representatives of THE GLASS INDUSTRY, were among the press correspondents invited to attend respectively the first and second tests on atomic bombs at Bikini. Much was added by these two keen observers, with their different points of view, to anything that had hitherto been read by their audience.

J. C. Hostetter made a graceful introduction of Professor Turner, tracing his early career as a physical chemist, and his entrance into the glass field as a result of his dissatisfaction with British laboratory glassware. Professor Turner then gave his address on the British Glass Industry in Wartime—an impressive account of the losses, dangers, and difficulties attending the manufacture of glassware under recurring attack and threat of invasion.

The Scarlet Course, O.S.U., 6800 yards, proved to be very tough for the Division's golfers. K. M. Henry, Kimble Glass Co., won the O. Hommel trophy with a low gross of 88. John Carruthers, local boy, had best net, with 93—19—74, and R. F. Hannum, Fostoria Glass Co., was second with 92—16—76. The deep water hazards hold the hopes of other contestants.

Following is the story told by Dr. Preston concerning his first meeting with Professor Turner and how the term Glass Technology came about.

The Inventor of Glass Technology

I suppose I have known Professor Turner a few years longer than anyone else in this gathering. Dr. Turner does not know this story, though he may remember the occasion. The only man beside myself that did know it has passed away. He was Mr. William Taylor, then Governing Director of Taylor, Taylor & Hobson Ltd.;

The Speakers' Table: R. F. Brenner, J. E. Hansen, J. S. Gregorius, W. E. S. Turner, O. G. Burch, Dean C. E. MacQuigg, Dean S. R. Scholes, Carl J. Uhrmann, H. H. Blau and Ross C. Purdy.

he was generally known as "W.T.," though I sometimes referred to him simply as "the boss." I have often said that he was the most insighted engineer that England produced between Whitworth, the pioneer in standardization, and Royce, the inventor of the Rolls-Royce engine.

Later "W.T." was to become a Fellow of the Royal Society, a distinction also accorded to Professor Turner, and he also became President of the Institute of Mechanical Engineers.

It was thirty years ago, and World War I was in full and unhappy fling. The scene was Taylor, Taylor & Hobson's factory at Leicester, England. "W.T." came into my office, and asked:

"Mr. Preston, what is Glass Technology?"

"Glass Technology? I never heard of it."

"Neither did I."

"In fact, there isn't any such subject."

"No such subject?"

"No. You haven't heard of it, and I haven't. It's impossible there should be any such subject."

"Well, that sounds reasonable, though I'm not sure there isn't a nonsequitur somewhere in the argument. Do you know Professor Turner of Sheffield University?"

"No. I'm afraid I don't know any of the professors at Sheffield."

"This is Professor W. E. S. Turner."

"I'm afraid I still don't know him."

"He is proposing to found a Department of Glass Technology at the University of Sheffield, and also a Society of Glass Technology, and he wants our support."

"Oh, I see. It is just something he invented: there isn't any such subject."

"Perhaps not, but he writes a good letter about it."

"He'd have to. No one could invent a term like that with impunity, unless he could back it up with a good letter."

"Well, he wants us to join the Society. I think the man has ideas; in fact, I think you and I ought to go to Sheffield and see him and size him up."

"I suggest you phone him, and I'll keep my calendar for the next few days free until I hear from you."

So we went to Sheffield and saw Professor Turner. I remember little of the interview, for the war and its miseries, the incessant slaughter of my friends, blurred the image of most other things. But I remember the subsequent conversation with Mr. Taylor.

"Strange fellow, this Professor Turner," said "W.T."

"Very strange."

"But evidently an able man."

"Undoubtedly, but I'd think better of him if he hadn't invented a term like glass technology."

"Well, he had to call it something."

"I suppose so, but I'm suspicious of college professors, especially when they invent terms like that."

"I think we ought to support him: in fact, we *will* support him. The man has ideas."

So Taylor, Taylor & Hobson became a corporate member of the Society of Glass Technology, and a few months later there reposed in my office two copies of Volume I of the Journal of the Society of Glass Technology, a volume now scarce enough to be a collector's item. I imagine that very few of you have a copy. But if you look at it, or at Volume II if you haven't Volume I, you will see that I was substantially right. There was to all intents and purposes no such subject as Glass Technology.

Then if you turn to one of the more recent volumes, say twenty years or so later, you will find that William Taylor also was right. "We ought to support him: in fact, we *will* support him: the man has ideas."

Ten years before my visit to Sheffield, Walter Rosenhain had published a book entitled, somewhat misleadingly, "Glass Manufacture."[1] The first edition was apparently in 1907, and the second in 1918. Rosenhain had been with Chance Brothers of West Smethwick, and presumably knew what little there was to be known in those days of the scientific aspects of glass making and the properties of the finished article. At the time of the second edition Rosenhain was an important member of the staff of the Natural Physical Laboratory of England, a Fellow of the Royal Society, and so forth. So his work cannot be dismissed as that of an amateur.

In 1938, twenty years later, George Morey published his "Properties of Glass."[2] The contrast is almost beyond belief. There is, now, such a thing as glass technology.

Mr. Chairman, these lowly organisms you see around you are glass technologists. They were unknown to science until thirty years ago, when they were discovered by Dr. Turner, and added to the fauna of the British Isles and North America. Their zoological affinities are obscure. From the hangdog look upon their countenances, some have concluded that they are intended to illustrate the old adage, "Give a dog a bad name and it will stick to him." The possibility that the creature is allied to the dog is enhanced, in the opinion of some, by the fact that the best place to catch one is around the dog-house.

Be that as it may, Mr. Chairman, there is no question as to their discoverer. These lowly creatures are glass technologists, Turner's glass technologists, *Technicus Vitrarius Turneri.*

Ergo, Francisce, si illius monumentum requiris, circumspice.[3]

Reviews of the two symposiums which were conducted during the two-day meeting follow.

Symposium on Glass Density

Mr. L. G. Ghering acted as Chairman of the extremely interesting and well attended symposium on glass density. Mr. Ghering, in opening the symposium, called attention to the fact that the many recent papers on the subject of glass density indicated that this old and often used laboratory test was beginning to become a useful tool for both control and research in the plants. The papers presented and the "from the floor" discussions proved the truth of this statement.

The symposium was opened by R. D. Duff, of the Owens-Illinois Glass Company, who discussed lehr sampling versus quenched rods drawn from the forehearth and thermal history differences. In brief, this quenched rod technique consists of drawing rods from the tank (spout or forehearth) followed by rapid cooling of the

(*Continued on page* 516)

[1]Constable, London.
[2]Reinhold Publishing Corp., New York.
[3]Editor's Note: The reference is to the inscription in St. Paul's Cathedral, London, to its designer, Sir Christopher Wren. "Si monumentum requiris, circumspice." Francisce, of course, here refers to Francis Flint, chairman of the meeting: "And so, Mr. Chairman, if you ask what memorial men have raised to yonder illustrious man, look around you."

COLOR AND SOLARIZATION OF GLASSES CONTAINING COMBINATIONS OF COLORING OXIDES

By L. V. GAGIN, G. S. BACHMAN, A. E. BADGER

Introduction

The colors produced by the various oxides in glasses have been studied from ancient times and are well known. The common coloring agents are titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and the rare earths. In glass these coloring agents are present in the form of ions, and the transmission of color by the glass is directly related to the ionic condition and environment of the coloring agent present. A comprehensive survey of color phenomena in glass has been published recently by W. A. Weyl.[1]

The colors produced by mixtures of the coloring oxides used in glasses have not been investigated thoroughly. Such colors are not always mere physical summations of the absorption of the coloring oxides acting independently of one another. At times the colorants react with one another, an oxidation-reduction reaction being most common. The iron-manganese combination color is an example of this effect. Turner and Weyl[2] state that in the presence of mere traces of ferrous oxide, the Mn_2O_3 is decomposed to MnO, and the FeO oxidized to Fe_2O_3.

The first part[3] of this investigation consists of a study of such combination colors. The coloring oxides mentioned above were supplemented by two rare earth oxides, and by the oxides of arsenic, antimony, and tin, since the latter might change the colors produced by the actual coloring agents by means of their effect on oxidation-reduction equilibria. The second part of this study deals with the "fading" or solarization of the glasses.

Preparation of Glasses

The color oxides used in the glasses, the proportions added, and the formulas of the additions are given in Table I.

TABLE I

OXIDES USED IN STUDY OF COMBINATION COLORS

Element Added	*Proportion*	*Form of Addition*
Ti	1/200	TiO_2
V	1/200	V_2O_5
Cr	1/1000	Cr_2O_3
Mn	1/200	MnO_2
Fe	1/1000	Fe_2O_3
Co	1/10000	Co_3O_4
Ni	1/1000	Ni_2O_3
Cu	1/200	CuO
As	1/200	As_2O_3
Sb	1/200	Sb_2O_3
Sn	1/200	SnO_2
Ce	1/200	CeO_2
Nd	1/200	$Nd_2(CO_3)_3$

Since thirteen color oxides were used, the combinations with each other yielded 78 glasses with mixtures of two oxides. The addition of the original 13 oxides gave a total of 91 glasses whose colors were studied.

The base glass batch used in this study was as follows:

Na_2CO_3	24.3 grams
$NaNO_3$	6.0
$CaCO_3$	18.1
SiO_2	72.5

This batch produced a glass having the approximate chemical composition 17.6% Na_2O, 10.1% CaO, and 72.3% SiO_2.

The batch constituents were weighed, mixed thoroughly, and fired in crucibles placed in covered saggers in a gas-fired furnace. The furnace was brought up to 1350 deg. C, held there for one hour, and then shut off. After the glasses had cooled in the furnace, they were chipped out of the crucibles, and the chips were remelted and cast into discs about one inch in diameter and one-eighth inch thick. The glasses were then tested on a General Electric automatic recording photoelectric spectrophotometer,[4] giving curves that showed the percentage transmission of wave lengths from 400 to 700 millimicrons. Some of the melts fined better than others, and the glasses were not polished, so minute variations in the curves were not held as indications of a change in the glasses.

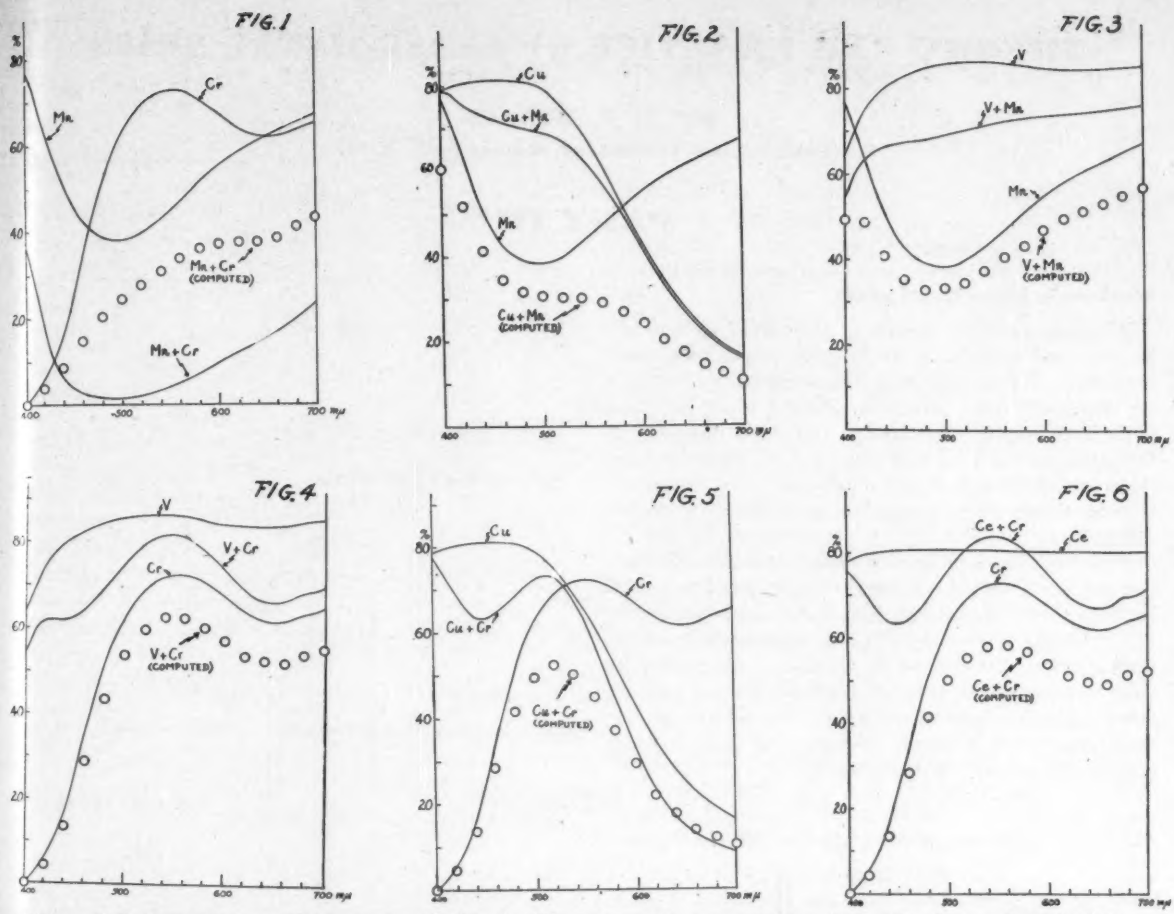
The glasses were then exposed to ultraviolet light from a quartz-mercury lamp for 100 hours at a distance of ten inches. After exposure, the glasses were again tested for transmission on the spectrophotometer. The fading of some of the glasses was determined after exposure to ultraviolet light for a period of 25 hours. Results of tests with the spectrophotometer showed that this period was nearly as effective as the 100-hour period. A much shorter period might be sufficient to produce the saturated color change, but this minimum period was not determined.

Colors Produced by the Combination of Two Oxides

The method used to study the colors produced in glass by the presence of two oxides consisted in melting three glasses, two of which contained the individual oxides, the third glass containing both oxides. The spectral transmission of these glasses was obtained and the curve corresponding to the combined oxides then compared with a computed curve. The latter curve represents the spectral transmission which would result if white light were passed through the two glasses which contained the separate oxides.

If the two oxides did not react when present in the same glass, the computed curve should be symmetrical with the spectral transmission curve of the glass containing both oxides. A deviation from symmetry denotes a chemical reaction between the two oxides.

For example, it is known that chromic oxide in glass tends to oxidize Mn^{2+} and thus form a deeper purple glass. Figure 1 illustrates this effect. The purple glass containing manganese is marked Mn; the yellow-green glass containing chromium is marked Cr. The spectral



Figures 1-6. Spectral transmission curves of glasses. The percentage transmission of samples (approximately 3.5 mm thick) is plotted against the wave length of light in millimicrons. Each figure shows the transmission on glasses containing only one coloring oxide as well as the transmission of a glass containing both oxides. The circles represent the transmission of white light through the two glasses which contain the separate oxides. Figure 1 shows the oxidation of divalent manganese by chromium when both oxides are present in the glass, forming a deep purple glass. Figures 2 and 3 indicate the reduction of trivalent manganese by copper and vanadium, respectively, with the formation of less color in the glasses. Figures 4, 5, and 6 show that vanadium, copper, and cerium oxides reduce hexavalent chromium, thus producing green glasses.

transmission curve of light passing through both of these glasses was computed and is shown by circles. If manganese and chromium did not react when present in the same glass, the spectral transmission of such a glass would be symmetrical to the curve delineated by the circles and somewhat above it. Figure 1 shows that the actual transmission curve of glass containing both oxides (denoted Mn + Cr) is greatly different from the computed curve, the explanation of the discrepancy being that the Cr^{6+} ion has oxidized the Mn^{2+} ion to the purple trivalent form.

The above method of investigation was used to study all combinations of two oxides listed in Table I. The results showed that, in general, glasses containing manganese or chromium were prone to react with other oxides. The results confirmed the already established facts of the reduction of trivalent manganese by the oxides of antimony, arsenic, and iron, as well as the reduction of hexavalent chromium by antimony. The curves shown in Figures 2 and 3 indicate that copper and vanadium will reduce manganese also.

With respect to chromium-bearing glasses, it was found that vanadium, copper, and cerium oxides act as reducing agents and increase the amount of trivalent chromium, thus producing green glasses (see Figures 4, 5 and 6). No other pronounced effects were observed.

Results of Tests on Fading

The fading of the glasses was measured by the difference in transmission of the visible wave lengths before and after exposure to ultraviolet light.

None of the glasses containing but one oxide showed much fading.

Most combination oxide glasses transmitted less after exposure than before. Those glasses showing the largest decrease in transmittance were: arsenic glasses with chromium, manganese, cerium, cobalt, and neodymium; manganese glasses with antimony, tin, copper, iron, and cobalt; chromium glasses with tin and neodymium; neodymium (commercial grade, containing cerium perhaps) glasses with tin and cobalt; and the vanadium-cerium glass.

Effect of Temperature on Fading

The original color of glasses which have been discolored by exposure to light may easily be regenerated by heating the discolored glass to a moderate temperature

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THEORY AND PRACTICE OF GLASS-METAL SEALS

By A. J. MONACK
Engineering Consultant, Rutherford, N. J.

PART III

Stresses in Glass Metal Seals

Whenever possible, stresses in glass-metal seals should be evaluated entirely on the basis of photoelastic measurements. This is advisable because calculated stresses are dependent upon several corrections which are often difficult to apply. For design purposes, however, an indication of the kind and magnitude of stress is sometimes necessary and always desirable. The theoretical aspects of stresses in glass-metal seals therefore deserve discussion.

Poritsky[14] has published a complete analysis of thermal stresses in sealed cylinders. The stresses in a beaded lead are three: radial, tangential, and axial (see Figure 15.). On the basis of Poritsky's fundamental equations Hull and Burger[11] derived the following expressions for these stresses in the glass of a beaded lead at any distance r from the axis of the wire. The differential free contraction of unit length of glass and metal between temperatures t_0 and t is designated δ.

$$\delta^* = k_{\text{metal}} - k_{\text{glass}})\ (t - t_0), \qquad (2)$$

where k = mean expansion coefficient between t_0 and t.

$$\text{Radial stress, } p_r = -\left[\frac{E_2\delta}{1+\alpha+\alpha\beta R}\right]\left[\frac{a^2}{b^2} - \frac{a^2}{r^2}\right], \qquad (3)$$

Tangential stress,

$$p_\theta = -\left[\frac{E_2\delta}{1+\alpha+\alpha\beta R}\right]\left[\frac{a^2}{b^2} + \frac{a^2}{r^2}\right], \qquad (4)$$

Axial stress,

$$p_z = -\left[\frac{E_2\delta}{1+\alpha+\alpha\beta R}\right]\left[2\sigma\frac{a^2}{b^2} + \frac{1+\alpha+\alpha\beta R}{1+\beta R}\right], \qquad (5)$$

where E_1 = Young's modulus of wire
E_2 = Young's modulus of glass
σ = Poisson's ratio (may be taken as 0.30)
a = radius of wire
b = radius of glass
r = radial distance from axis of wire
$R = E_2/E_1$
$\alpha = (a^2/b^2)\ \ (1-2\sigma)$
$\beta = b^2/a^2 - 1$

For all values of a/b and r the radial stress is positive (tension) when δ is positive, and decreases from a maximum value at the surface of the wire to zero at the surface of the glass (normal stress always zero at a free boundary). The tangential and axial stresses are negative (compression) when δ is positive, and again are maximum at the wire surface. The axial stress is constant over the cross section, while the tangential stress decreases in the ratio of $(a^2 + b^2):2a^2$ from the wire to the surface of the glass.

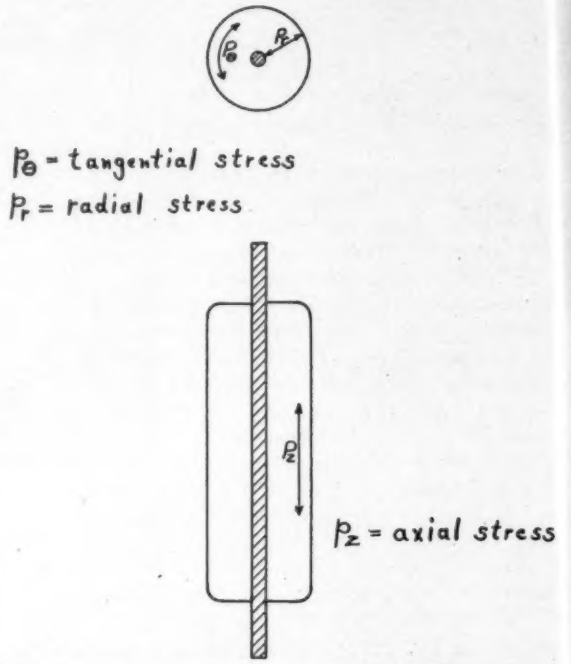


Fig. 15. The three principal stresses in the glass of a beaded lead.

In Figure 16 the above relationships are plotted for $E_1 = 1.8 \times 10^6$ kg/cm^2 and $E_2 = 0.65 \times 10^6$ kg/cm^2. The ordinates are stresses per unit difference of expansion or contraction and the abscissas are ratios of glass to wire diameter. If δ, the differential free contraction, is known for a wire-glass combination, with t usually taken as the annealing point of the glass, it is only nec-

TABLE 6

TYPES OF STRESS DURING HEATING AND COOLING

1. Expansion of glass greater than expansion of metal ($k_g > k_m$)
   a. On cooling
      Radial stress, p_r = (−) compression
      Tangential stress, $p\theta$ = (+) tension
      Axial stress, p_z = (+) tension
   b. On heating
      Radial stress, p_r = (+) tension
      Tangential stress, $p\theta$ = (−) compression
      Axial stress, p_z = (−) compression
2. Expansion of metal greater than expansion of glass ($k_m > k_g$)
   a. On cooling
      Radial stress, p_r = (+) tension
      Tangential stress, $p\theta$ = (−) compression
      Axial stress, p_z = (−) compression
   b. On heating
      Radial stress, p_r = (−) compression
      Tangential stress, $p\theta$ = (+) tension
      Axial stress, p_z = (+) tension

The above relationships do not hold for Dumet because of the difference between radial and longitudinal expansions.

*The algebraic sign of δ is correct for cooling if Equation (2) is used as written. For heating, the algebraic sign is correct if $\delta = (k_{\text{glass}} - k_{\text{metal}})\ (t - t_0)$.

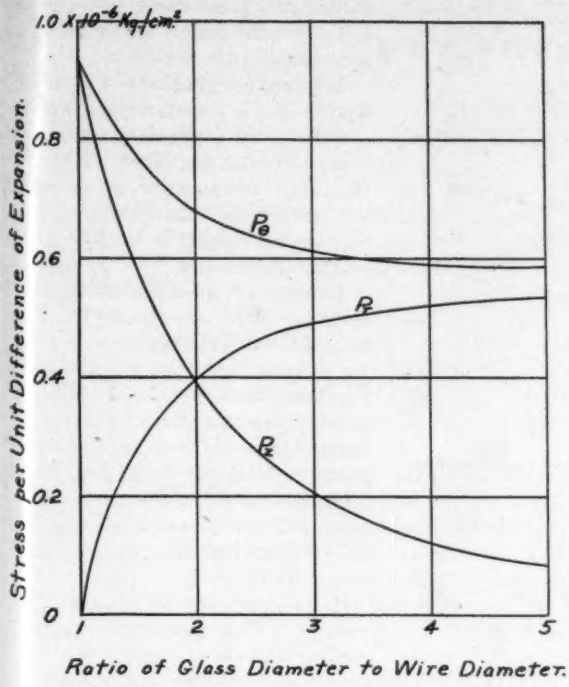


Fig. 16. Relation between stresses and dimensions in a beaded lead.

essary to multiply δ by the proper ordinate from Fig. 16 in order to know the theoretical stress in the glass at the wire surface.

Because of the confusion and error likely to result from incorrect algebraic signs for δ in Equations (2), (3), (4), and (5), Table 6 is included here. By means of this table the kind of stress (tension or compression) can be determined in all cases where the expansion coefficient is equal in both radial and longitudinal directions.

Jonas[40] gives the following equation for computing the maximum radial stress in the glass of a beaded lead.

$$p = \frac{E_g \cdot \delta}{\rho_g\left(\frac{E_g}{E_m}\right) + \frac{\gamma n^2 + \rho_m}{n^2 - 1}}, \qquad (6)$$

where E_g = modulus of elasticity of glass
E_m = modulus of elasticity of metal
δ = difference in expansion per unit length between glass and metal for the temperature interval under consideration
n = ratio of glass diameter to metal diameter

$$\gamma = \frac{1 + \mu_g\,[1 + (n^2 - 1)\,E_g/E_m]}{(1 + \mu_m) + (n^2 - 1)\,(1 + \mu_m)\,E_g/E_m} \leqq 1$$

$\rho_g = 1 - 2\,\mu_g$
$\rho_m = 1 - 2\,\mu_m$
μ_g = Poisson's ratio of glass
μ_m = Poisson's ratio of metal

Equation (6) is equivalent to Equation (3).

40. Jonas, B., *Philips Tech. Rev.*, **3**, 119-24 (1938).
41. Scott, H., *J. Franklin Inst.*, **220**, 733-53 (1935)
42. Love, A. E. H., *A Treatise on the Mathematical Theory of Elasticity*, 4th Ed., Cambridge Uni. Press, 1934, p. 142.

The radial stress σ_r as a function of the distance r from the axis of the wire is given by the equation:

$$\sigma_r = \frac{p}{n^2 - 1}\left(\frac{r_g^2}{r^2} - 1\right), \qquad (7)$$

where r_g is the radius of the glass bead and the other terms are as defined above.

Scott[41] has computed the following expressions for radial stress, S_r, and tangential stress, S_t, in a beaded lead.

$$S_r = P\frac{a^2}{b^2 - a^2}\left(\frac{b^2}{r^2} - 1\right), \qquad (8)$$

$$S_t = -P\frac{a^2}{b^2 - a^2}\left(\frac{b^2}{r^2} + 1\right), \qquad (9)$$

where a is the radius of the metal wire, b the radius (outside) of the glass, r the radial distance from the wire axis to the point considered, and P the maximum radial stress. Equation (8) is of course merely another expression of Equation (7). At the boundary of wire and glass the ratio of tangential to radial stress is:

$$\frac{b^2 + a^2}{b^2 - a^2}, \qquad (10)$$

Wichers and Saylor[2] have presented the following equation for use in estimating the radial stress q at the glass boundary in an internal tube seal of the type shown in Fig. 9a.

$$q = \frac{(\alpha_1 - \alpha_2)\,\Delta t}{\frac{1}{E_2}\left(\frac{c^2/b^2 + 1}{c^2/b^2 - 1} + \mu_2\right) + \frac{1}{E_1}\left(\frac{b^2/a^2 + 1}{b^2/a^2 - 1} - \mu_1\right)}, \qquad (11)$$

where
α_1 = thermal expansion coefficient of the metal
α_2 = thermal expansion coefficient of the glass
E_1 = Young's modulus of the metal
E_2 = Young's modulus of the glass
μ_1 = Poisson's ratio of the metal
μ_2 = Poisson's ratio of the glass
Δt = difference between temperature at which the glass ceases to flow and the temperature at which the system is observed
a = inner diameter of the metal tube
b = outer diameter of the metal tube = inner diameter of the glass tube
c = outer diameter of the glass tube

Considerable emphasis has been placed in the literature on methods for computing radial stress. This stress is tensile when the expansion of the metal is greater than that of the glass. On the other hand, when the expansion of the glass is greater than that of the metal, the radial stress is compressive while the tangential and axial stresses are tensile. Since the tangential stress is always greater in magnitude than the axial stress tangential tension is the limiting stress. Radial cracks, which are not at all uncommon in many types of seals, result from tangential tension at the wire-glass interface.

Equations (3) to (11), all based on Lamé's theory[42] are correct in a mathematical sense and may be used, for

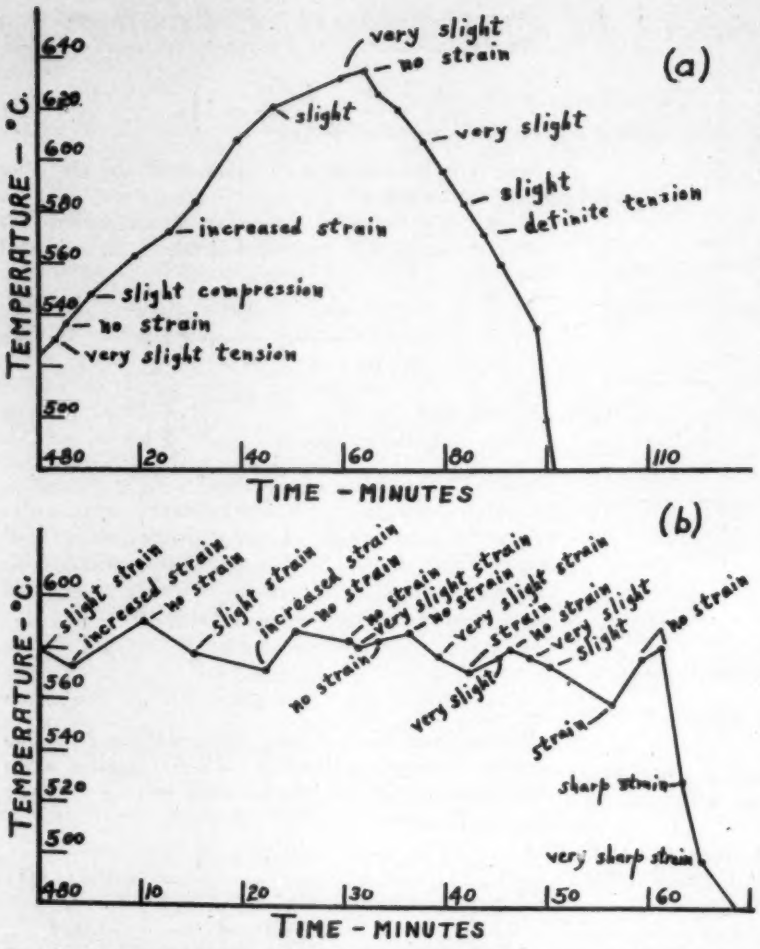


Fig. 17. (a) Temperature-strain relationship in a glass-tungsten seal; (b) effect of repeated heating and cooling on strain in a glass-tungsten seal.

lack of more definite information, to estimate the probable stresses in a glass-metal seal. There are several reasons why the computed stresses are to be considered probable stresses or "working estimates" for design purposes. Several of these reasons are treated below.

(a) *Rates of cooling of glass and metal.* All theoretical aspects of stress in a beaded lead are based on an assumption of uniform temperature throughout glass and metal, this temperature uniformity persisting to room temperature. This assumption of uniform temperature is not in accordance with actuality. Because the thermal conductivity and emissivity of metal are always higher than those of glass a radial temperature gradient exists from the outside of the seal to the center of the wire. This has two effects in the finished seal at room temperature. In the first place, the metal, being at a lower temperature than the glass, contracts less than the theoretical amount. In case the metal expansion curve is above that of the glass at the annealing point of the latter the lower temperature of the metal tends to reduce the strain in the finished seal. In effect, the case is equivalent to one of a metal of lower expansion. Contrarily, if the expansion curve of the glass is above that of the metal at the annealing point the expansion differential is exaggerated and the strain at room temperature is higher than the theoretical value. If glass cools faster than metal the theoretical stress value is again subject to correction.

Temperature gradients in the glass tend to give a situation equivalent to shrinkage of successive concentric rings one upon the other. Actually no sharp demarcation is observed but theoretical considerations are nevertheless subject to modifications because of this fact.

Temperature gradients of the type discussed above are the reason why more difficulty is encountered in making a large seal than a small one. The theoretical stress values depend purely upon the ratio of glass to metal diameter, but as the actual diameters get larger more and more manipulative difficulties are encountered and the stress often exceeds the calculated amount by a considerable margin.

(b) *Plastic flow of glass during cooling.* With moderate rates of cooling, glass continues to flow under stress between the annealing point and the strain point. There is good evidence that flow may be appreciable even below the strain point. If the annealing point is taken, in a theoretical analyses, as the temperature below which glass does not yield under stress errors of considerable magnitude are introduced. Continued flow under the large stresses caused by differences in contraction of glass and metal have the effect of decreasing the value of the differential free contraction, δ, in Equations (3), (4), and (5), and stress in the glass at room temperature is consequently less than the calculated amount.

Poritsky[14] has given a rigorous treatment of the effect of flow and Hull and Burger[11] have, by means of certain assumptions, calculated the effects of flow in two examples. Because of the unknowns in such calculations they are of rather limited value in actual practice. It must be kept in mind, however, that viscous or plastic flow does modify calculated stresses in the glass of glass-metal seals.

(c) *Change produced by heat treatment.* As stated previously, in connection with Fig. 14, glass cooled at ordinary rates is not in equilibrium and will change its characteristics if held for a long time at one temperature. Thus, the magnitude of the expansion changes if a glass is held at the annealing point or at the strain point. The magnitude also changes with different rates of cooling. These variables require correction in the calculated values of stress in a seal. Since the factors required for such correction are never known with exactitude the applied correction is usually merely an estimate or approximation. The changes in expansion characteristics induced by variations in the rate of cooling of a seal are nevertheless sufficient in some instances

(*Continued on page* 522)

RAILROADS STUDY BONDED-BLOCK METHOD OF CARTON LOADING

By W. GRANT BURDEN
Union Pacific Railroad Company

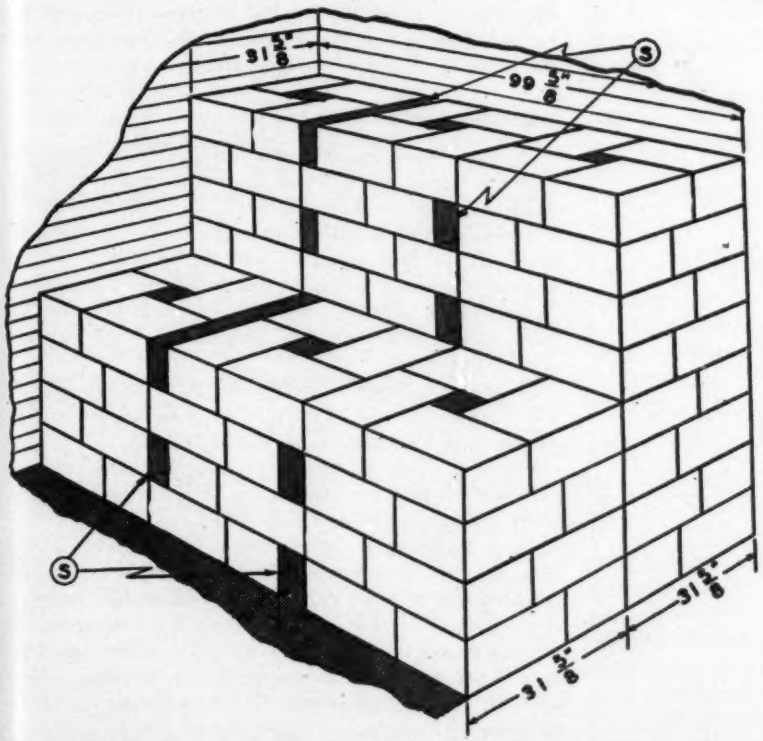
The old adage to the effect that there's a little good in the worst of us applies to a certain degree to the recent wasteful war, out of which came fibreboard packaging procedures that can be marked down as the greatest advancement in the art of shipping in many long years. It is these improved methods which today portend the safe delivery of additional goods to dealers throughout the country and at least the partial salvaging of a considerable annual monetary loss suffered by producers of glassware and the nation's railroads.

The big post-war strides that packaging and container engineers have made in combating rail shipment losses in goods packaged in fibreboard containers have been spurred by the following bit of cold logic: 1. There exists today, as in the past, a heavy damage rate among goods shipped in cartons. 2. A tremendous increase in the shipment of glassware in fibreboard cartons means that the amount of damage suffered in the rail shipment of this type of lading has bounded upward. Inexperienced help has been a contributing factor to the increase in damage but of paramount importance in the matter of damage is the fact that inferior materials have had to be used due to wartime shortages. 3. The tight world-wide commodity situation means that loss due to rail shipment damage must be substantially reduced. How the damage rate has skyrocketed can be appreciated with the knowledge that the number of ton-miles hauled over the railroads of the United States has more than doubled since 1939. For instance, the Union Pacific Railroad, in conjunction with a study of the extent and problems of shipments of bottles, jars, and jelly glasses, compiled the following tabulation:

Year	Tons moved over U. P.	Increase over 1939
1939	33,147	
1940	38,131	15.0%
1941	53,474	61.3
1942	85,254	157.2
1943	145,717	339.6
1944	150,414	353.7
1945	167,429	405.1

It is because of this tremendous increase that the problem of damage-free shipping has become so important.

Before World War II only one loading method was used in the shipment of fibreboard boxes. That was the age old system of stacking the boxes in rows as tightly as possible to prevent shifting. As many of the boxes as possible were loaded lengthwise to provide additional strength against front to rear and rear to front shifting, but it was often necessary to stack some rows crosswise to adequately fill gaps along side walls and in the door area.



The bonded-block method of loading showing the stacking of fibreboard cartons 18⅞ inches in length, 12¾ inches width and 7⁹⁄₁₆ inches in height. The circled S indicates points where crosswise slack is left in the load. It should be noted that the slack is alternated, with the space left at right of the center section of the blocks in the odd layers and at the left in the even layers.

However, in the year prior to the Pearl Harbor attack, the Association of American Railroads had its eye on a new system of fibreboard carton loading—the bonded-block method.

This method, which entered the experimental stage in 1940 with shipments from points in Texas' Rio Grande Valley, provides for the stowing of boxes in a series of blocks, each of which is bonded together both lengthwise and crosswise of the car. The system might be likened to the way in which bricks are bonded together in the construction of a wall or pier.

The Association of American Railroads smiled favorably upon the bonded-block method in a pamphlet published in 1941. The bonding principle was lauded as advantageous in that it increased the equilibrium of the load and tended to prevent or at least minimize the tilting of stacks.

(*Continued on page* 518)

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Glass Compositions

Patent No. 2,407,874 on a batch for making optical glass was assigned to Bausch & Lomb Optical Company by the inventor, Walter A. Fraser. This glass is one of those having relatively high reciprocal dispersions and low indices. Such glass has been obtained previously by adding fluorine in some form to the batch. This resulted in an excessive loss of fluorine during the melting.

This inventor has discovered that this loss may be greatly reduced if the fluorine is added in the form of an alkali metal acid fluorine instead of the fluorides heretofore used. The resulting glass has a lower refractive index and higher reciprocal dispersion than most of the glasses made by the old method.

It is believed that the alkali metal acid fluoride decomposes at a temperature lower than that necessary with the fluorides previously used and that the fluorine is captured and retained by the glassy matrix in an early stage of the melting. The patent contains an interesting discussion of the chemical actions and effects of the various ingredients formerly used and those used in this invention. It is preferred to use the fluorine in this batch in the form of potassium. Acid fluoride or sodium acid fluoride are readily obtained in a pure state and at a reasonable cost.

The following table gives four batch compositions for optical fluor-crown glasses in accordance with this invention:

	I	II	III	IV
SiO_2	300	300	300	300
K_2CO_3	25.8	19.5	59.8	....
KNO_3	18.9	14.2	43.8	....
KHF_2	168.4	105.2	52.8	....
Na_2CO_3	....	....	....	56.8
$NaNO_3$	....	....	....	45.6
$NaHF_2$	....	....	....	179.6
H_3BO_3	212.2	45.4	171.8	158.4
$Al(OH)_3$	....	78.4	82.8	158.1
As_2O_3	0.63	0.51	0.57	0.69

The invention is also capable of use in making opal glass, enamels, etc., in which case the two following compositions are given:

	I	II
SiO_2	300	300
Na_2CO_3	77.7	21.0
$NaNO_3$	62.3	16.8
$NaHF_2$	64.6	150.6
H_3BO_3	43.9	40.8
$Al(OH)_3$	75.8	....
As_2O_3	0.5	0.5

Patent No. 2,406,580, on a composition for optical glass, was assigned to Chance Brothers of England by the inventors, Bastick, Hampton and Ta-Hang Wang.

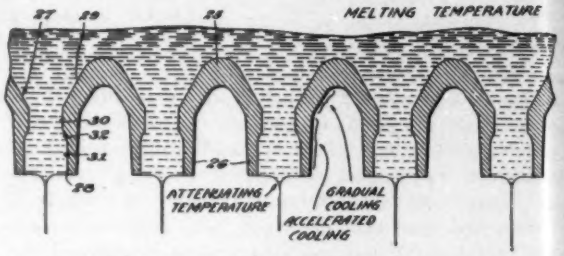


Fig. 1. Owens-Corning Fiberglas Patent.

This glass is particularly adapted for use in photographic lenses and it is recommended that it be melted in a platinum crucible. Lead oxide with or without other oxides of alkaline earths may be added to the composition as set forth in Claim 1, which is as follows:

Optical glasses having the following essential constituents and within the range of proportions specified, namely:

	Per Cent
Silica (SiO_2)	10-25
Barium oxide (BaO)	15-35
Boron oxide (B_2O_3)	10-30
Lanthanum oxide (La_2O_3)	8-20
Thorium oxide (ThO_2)	3-15
Zinc oxide (ZnO)	2- 8

the amounts of lanthanum and thorium oxides together being not more than 35 per cent of the total glass composition.

Glass Wool and Fiber

Patents No. 2,407,295 and 2,407,456 are improvements in the manufacture of glass filaments invented by Allen L. Simison and Ed Fletcher and assigned to Owens-Corning Fiberglas Corporation. The first named patent is on the apparatus and the second is on the method which was divided from the earlier application. As the patent drawings are identical and the specifications quite similar, the two patents may well be considered together.

Reference is made to Patent No. 2,291,289 to Slayter and Thomas for a disclosure of the principle of flowing molten glass through a small orifice and then attenuating the stream. This requires a very careful control of temperature whether the attenuation is done mechanically, as by a drum, or by a gaseous blast.

These two patents provide means for obtaining a very accurate control of temperature of the glass as it is attenuated and a rapid reduction of temperature immediately thereafter. The control of the glass temperature is complicated by the metal wall of the orifice which is usually employed. These patents show a metal orifice which is cool enough to prevent it from being wetted by the glass.

Fig. 1 is a section through a metallic bushing having a bottom 25 provided with a series of tips 26 from which the glass fibers may be drawn out as taught by Patent No. 2,133,236 to Slayter and Thomas. Each tip has a

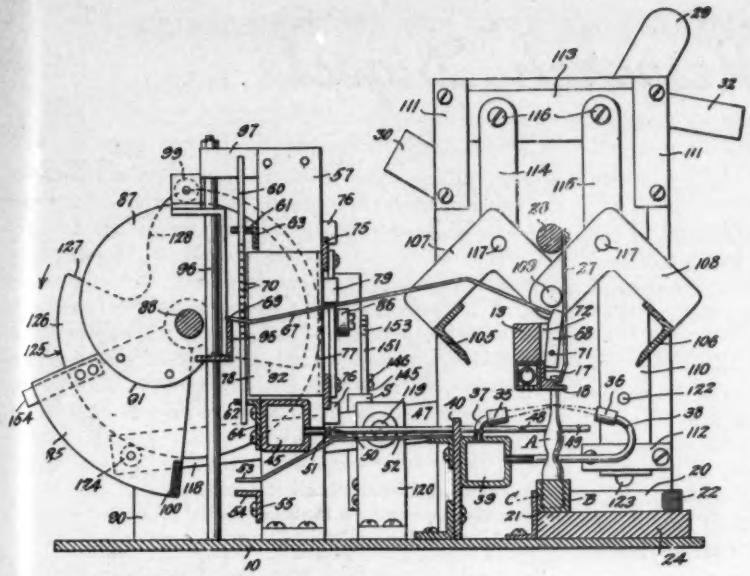


Fig. 2. Machine for Sealing Ampoules.

central passage 27 leading to the atmosphere at 28. The passage 27 is tapered as shown at 29 and also has a straight portion 30 leading to an enlarged passage 31. The walls of the tips decrease in thickness from top to bottom, there being a sudden decrease in thickness at 32. These tapered walls cause the glass to cool as it flows outward. When the glass reaches the enlarged passage 31, its rate of flow will be decreased which will increase the rate of cooling so that when it reaches the bottom of the tip at 28 it will have the desired attenuating temperature. A tip having walls of decreasing thickness and a constriction intermediate at its ends has decided advantages over a straight passage.

Three modifications of the tip are shown in the patents all of which present the same advantages.

Patent No. 2,407,483 covers a method of treating fabric made of glass fibers. It was assigned to Owens-Corning Fiberglas Corporation by Paul Ebaugh of Granville, Ohio, the inventor.

The patent discloses the method of treating a woven fabric of glass yarn to reduce the diameter of the individual fibers by subjecting fabric to a solution of an inorganic alkali selected from the group consisting of potassium hydroxide and sodium hydroxide for a time sufficient to reduce the diameter of the fiber and then neutralizing the alkali and washing it from the fabric by an acid wash.

This method results in the production of a fabric having superior qualities for many purposes.

Miscellaneous Processes

Patent No. 2,406,101 is on a machine for sealing ampoules, an invention of Alf Pipping of Bloomfield, N. J.

Ampoules having the same capacity vary considerably in neck diameter and, therefore, require more or less time to heat the neck to the softening point. This invention provides an automatic sealing machine in which the duration of the application of heat is determined by the diameter of the neck of the ampoule. This insures proper sealing of every ampoule regardless of the neck diameter.

Fig. 2 is a section through the machine and it shows an ampoule A which is one of a series carried in sockets C formed in a rack B. The base 10 of the machine supports an interchangeable shim 24 positioned by a strip 21 so that ampoules of different heights can be positioned with their necks at the same level. A water cooled crossbar 13 carries a strip 17 having a series of notches to receive the necks. The necks are held in the notches by fingers 27 depending from a rock shaft 28 which is turned by hand to and from operative position as shown in the figure.

The ampoule necks are heated by flames from nozzles 35 and 36 which receive gas from pipes 37 and 38 leading to a supply manifold 39. The application of flame to the neck is controlled by jets of air from openings 48 and 49 in a pipe 47 leading to an air manifold 45. When this air is cut off by a valve 51, the flame is directed against the necks, but when the air is admitted to the pipe 47, the air from the openings 48 and 49 blows the flame upwardly and stops the heating of the neck. The valves are actuated by springs 53 which are depressed at the proper time to permit the flame to heat the neck by a series of rack bars 60, there being a bar for each valve.

Each rack bar 60 is set in a position determined by the diameter of the neck of the ampoule being operated upon. The spring fingers 27 will vary in position in accordance with the diameter of the neck engaged thereby. A gage head 68 pivoted at 71 is positioned by contact with the spring 27. Each head carries an arm 67, the free end of which is in operative relation with teeth 70 formed on the rack bar 60. A frame 75 moves the arms 67 to and from engagement with the teeth 70 on the rack bars 60 at a time determined by a cam 85. Thus the rack bars 60 will be picked up by an upwardly moving bar 95 at different times as determined by the diameter of the neck being treated and the valve 51 will be closed to permit the larger diameter necks to be subjected to a longer heating period.

The ampoules are sealed by jaws 105 and 106 carried by bell crank levers pivoted together at 109. The jaws are opened and closed at the proper time by a slide 110 acting through links 114 and 115. The slide is reciprocated vertically by 118 actuated by a cam 126. The shaft 88, which regulates the operation of the machine, is turned through one revolution when the operator throws in a clutch.

Patent No. 2,407,878, on a machine for heating glass, sealing electric lamps, for example, was granted to Ernest Greetham of London, England.

Machines of this kind in common use are of the turret type in which a series of rotary work carrying heads are advanced step by step to a corresponding series of work stations. Each station has a fixed burner which plays upon the work while it rotates. In order to gradually heat the work, the heat of successive burners increases

(*Continued on page* 529)

Research Digest

Unusual Colors Produced by Uranium in Glass

In this study by Colbert and Kreidl (*Journal of the Optical Society of America*, November, 1945), uranium was introduced into several base glasses of uncommon composition and glasses with unusual transmission spectra were obtained.

One of these glasses (a lead metasilicate containing aluminum) exhibits a truly red color. Hitherto, red colors were obtainable only in glasses of the gold, copper, antimony sulfide and cadmium sulfoselenide ruby type. Such glasses are strongly affected by heat treatment as they contain non-ionic colorants. The red uranium glass has color centers which are ionic in character and, therefore, remain unaffected by thermal treatment and, as a consequence, is strictly reproducible.

Transmission curves are given for a) the uranyl group in a Na_2O, $4SiO_2$ glass, b) the uranate group in a low silica lead glass, c) the influence of uranium concentration (0.5 to 4.0 weight % $Na_2U_2O_7$) in lead metasilicate glass, d) the influence of aluminum oxide addition to lead metasilicate, e) uranium-containing barium crown, f) the influence of nedymium oxide on the cutoff of a uranium-containing barium crown, g) uranous ion in a Na_2O, $4SiO_2$ glass, h) uranous ion in a borosilicate glass, i) extension of h to 1200 mμ in the infrared, j) uranous ion in Na_2O, RO, $4SiO_2$ glasses where R = Ca, Sr, Ba, Mg or Zu, and k) uranous ion in phosphate glasses: 1. barium aluminum, 2. potassium barium and 3. potassium zinc—in all three cases with and without a reducing agent.

The uranyl glasses show a yellow color and a strong green fluorescence due to the hexavalent uranium ion, U^{6+}, in the uranyl $(UO_2)^{2+}$ group. In this group, two oxygens are so close to the uranium that the excess positive charge makes this group act like a divalent cation. These color centers usually form when uranium is introduced into normal soda lime silicate or into alkali borosilicate glasses. They seem to be stable in all glasses having a sufficient supply of glass-forming oxides, such as silica or boric oxide.

As the amounts of glass-forming oxides decrease and those of other constituents, such as alkali, increase, the hexavalent uranic ion changes from the cationic uranyl to the anionic uranate group. Fluorescence decreases and the yellow color characteristic of the uranate group becomes more pronounced. In high lead silicate glasses, the absorption edge of the uranate group is shifted to longer wave-lengths. This leads to a group of glasses whose colors vary from orange to deep red. A red color can be produced in high lead silicate glasses apparently because of the loosening of the outer electrons of the uranium by the lead ion. Those glasses which contain less lead oxide than the lead metasilicate $PbSiO_3$, show an orange rather than a red color.

Tetravalent uranous ion, U^{4+}, forms upon reduction, particularly in glasses rich in glass-forming oxides. Fluorescence disappears and green, brown or gray colors appear. These color shifts are caused by a change in the equilibrium between uranic and uranous ions. From the light absorption at 540 mμ, one may judge the concentration of uranous ions in the glass. In phosphate glasses, the bands are particularly sharp and the transmission is limited almost exclusively to the two wave-lengths in the yellow and green and to the boundaries of the visible range. In the presence of aluminum or zinc oxides, both of which strengthen the network of phosphate glasses, the uranous ion is favored even in the absence of a reducing agent.

Influence of Batch Mixing Time and Batch Grain Size on Homogeneity of a Soda-Lime-Silica Glass

In previous papers, Tooley and Tiede have reported on the effect of time and temperature on the rate of homogenizing of a soda-lime-silica glass. In the present paper (*Journal of the American Ceramic Society*, July, 1946), the effect of grain size of raw materials and of batch mixing has been studied and reported.

For the study of the effect of batch grain size on the homogenizing rate, melts were prepared from batches representing five ranges of size, namely, 20 to 60, 60 to 80, 80 to 140, 140 to 200 and minus 200-mesh. Mixing was accomplished in a quart jar, tumbling end over end at approximately 40 r.p.m. Three mixing times were observed, namely, one, ten and thirty minutes. Two different melting procedures were used: in the first, the batches were melted for sixteen hours at 1400°C. under conditions of minimum convection mixing, that is, under conditions of even temperature distribution and in stationary crucibles. In the second procedure, meeting was carried out for four hours at 1400°C. in a crucible inclined 12 degrees from the vertical and rotating at 1⅛ r.p.m. This technique was employed in order to simulate to some extent the convection mixing that occurs in the commercial glass manufacturing process.

After the experimental glasses were annealed, then density spreads were determined by the centrifuge technique developed by Turnbull and Ghering.

From the results obtained in this study, it was concluded that 1) batch mixing time has relatively little influence on the homogenizing rate, 2) homogenization increases rapidly with decrease in grain size and 3) in the case of all grain-size ranges employed (5 ranges, from 20- to 60- to minus 200-mesh) a 4-hour treatment with moderate mixing (inclined furnace) gives better homogeneity than 16 hours melting time in a stationary crucible.

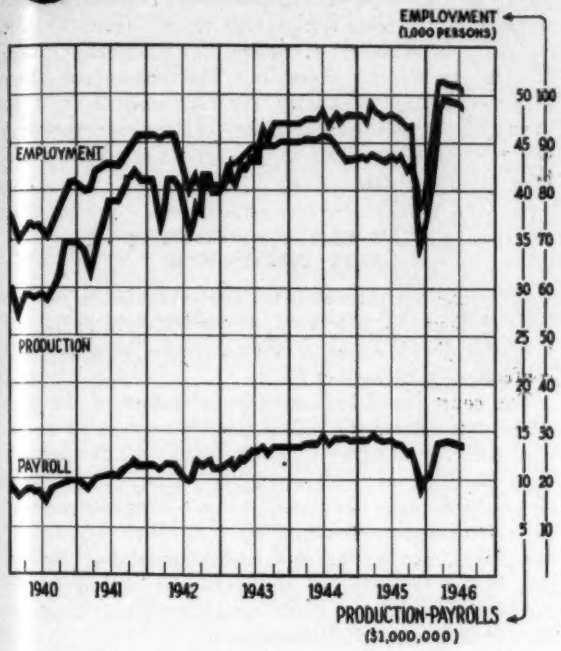
Three different types of batch mixing, namely, tumbling in a quart fruit jar, mixing in a laboratory-size Simpson intensive muller-type mixer and ball milling, result in no significant difference in glass homogeneity under the melting conditions observed.

In the discussion of this study and the previous two studies, the authors state, "The degree of homogeneity

(*Continued on page* 512)

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



July activity in the glass industry, as shown by the Production Index, varied about 1½ per cent from production reported during June. Production during July was an estimated $48,000,000 as compared with $48,800,000 reported during June. July 1945 production was about 4 per cent under July this year—or $46,000,000. The total estimated production at the end of the first seven months of 1946 is $332,000,000. At the end of the corresponding period in 1945, production was at the same estimated total as for this year.

Employment and payrolls: Employment during the month of July dropped about 1 per cent to about 100,000 persons employed. The June figures was approximated at 101,300. During July 1945, employment was estimated to be 86,300 persons, which is about 15 per cent under July this year.

Payrolls also dropped during July. They were estimated to be $13,000,000 in comparison with the $13,200,000 reported for June. During July 1945, glass manufacturers paid out about $12,500,000—or 12 per cent under July this year. Thus far this year, payrolls have reached a total of approximately $80,000,000. During the same period last year, payrolls were $95,700,000.

Glass container production, based on figures released by the Bureau of Census, continues its upward swing to total 10,658,710 gross for the month of August. This represents an approximate 10 per cent increase from the 9,604,432 gross reported during July. Production during August 1945 was 9,296,362 gross—or about 12 per cent less than August this year. Total glass container production at the close of the January-August 1946 period totals 76,448,215 gross. During the same period in 1945, production had reached a total of 69,023,360 gross. This is about 10 per cent below production this year.

Shipments for August also showed an increase. August shipments were 10,650,866 gross, as compared with 9,232,410 gross shipped during July. This represents a difference of about 15 per cent. August 1945 shipments were 9,519,575 gross—or about 11 per cent below August this year. Shipments made thus far in 1946 total 76,471,649 gross. Shipments during the same period in 1945 were 8 per cent below this figure, or 70,650,296 gross.

Stocks on hand at the end of August were 3,924,890 gross as compared with 4,089,662 gross at the end of

(*Continued on page* 512)

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production August 1946	*Stocks August* 1946
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials; Toiletries & Cosmetics	Narrow Neck	3,837,091	1,972,303
	Wide Mouth	3,637,191	1,028,111
Dairy Products		351,365	134,757
Beverages, Returnable		632,206	281,949
Beverages, Non-returnable		.....	.....
Beer, Returnable		396,062	80,910
Beer, Non-returnable		53,740	16,146
Liquors		922,080	151,871
Wines		370,669	53,105
Home Canning & Packers' Tumblers		458,306	205,738
Total		10,658,710	3,924,890

GLASS CONTAINER SHIPMENTS

(All figures in gross)

Narrow Neck Containers	*August* 1946
Foods	1,287,464
Medicinal & Health Supplies	1,173,541
Chemical, Household, Industrials	606,356
Beverages, Returnable	614,666
Beverages, Non-returnable	.....
Beer, returnable	362,688
Beer, Non-returnable	54,219
Liquors	890,798
Wines	361,700
Toiletries & Cosmetics	650,816
Sub-Total (Narrow)	6,002,248
Wide Mouth Containers	
Foods	3,108,441
Dairy Products	332,154
Medicinal & Health Supplies	261,316
Chemical, Household, Industrials	110,460
Toiletries & Cosmetics	134,892
Home Canning & Packers' Tumblers	456,428
Sub-Total (Wide)	4,403,691
Total Domestic	10,405,939
Export Shipments	244,927
Total Shipments	10,650,866

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G.C.M.I. ANNUAL MEETING

The Annual Meeting of the Glass Container Manufacturers Institute is scheduled to be held at Miami Beach, Florida, on December 2, 3 and 4, 1946.

Meetings scheduled for December 2 and 3 will be under the auspices of the Board of Trustees for the purpose of receiving semi-annual reports from the nine standing committees and making this information available to the industry generally. The semi-annual Membership Meeting, scheduled for December 4, will be open only to glass container and closure manufacturers and allied and supplier companies that are regular members of the Institute.

FLAT GLASS ANTITRUST SUIT POSTPONED

Trial of the flat glass antitrust suit scheduled to start in Federal Court on October 7 was indefinitely postponed by Judge Frank Kloeb at the conclusion of a pre-trial conference on September 6.

The court heard arguments on a motion of the government to amend the bill of particulars seeking to extend the case to cover a period from 1917 to the time of filing last year. Stuart Wall, counsel for Libbey-Owens-Ford Glass Company, said the proposed amendment increased from 20 to 60 individuals accused of conspiracy, carried the case back into another generation in the industry and was really an amendment to the bill of complaint which would require at least six months additional trial preparation.

George D. Welles, representing Fourco Glass Company, said his company was not organized until 1935 and said it was difficult finding records back to 1928, without extending back to 1917. Curtis Shears, special assistant to the attorney general, in charge of the government case, said the motion merely was to put defendants on notice as to certain evidence which would date back to 1917.

The court also announced the filing of a consent decree on the part of Corning Glass Works eliminating that defendant company from the trial. Under terms of the decree, the company is prohibited from having any interest in the flat glass business or entering into any agreement with other defendant companies.

The government objective of breaking up major companies named as defedants to the suit was said by counsel for defendants to be an issue upon which all compromise discussions had been hopelessly deadlocked.

A.S.T.M. ANNOUNCES NATIONAL MEETINGS

The American Society for Testing Materials has announced the dates for its 1947 National Meetings.

The 1947 Spring Meeting and Committee Week has been announced for February 24 through 28 and will be held in Philadelphia. The Annual Meeting, which will be the Society's fiftieth, will be held in Atlantic City from June 16 through 20.

ERRATA: In Dr. Preston's article on atomic bombs in the September issue, Page 445, column 1, line 8, for *climatic* read *climactic;* and in footnote of that column for $4_{\pi}{}^{2}$ read $4_{\pi}r^{2}$.

NEW EQUIPMENT AND SUPPLIES

IMPROVED DUST COLLECTOR

Aget-Detroit Company, First National Bldg., Ann Arbor, Michigan, has announced improvements in the Model 1150 Dustkop dust collector which have been made to increase its efficiency under the extremely heavy dust loads in buffing and polishing work.

While still retaining the combination of cyclone separator and spun glass filter as first and second stage air cleaners, a high compression filter, a new type filter seal and cyclone stack deflector have been added.

The high compression filter has the effect of stopping all the particles of lint and polishing dust at its surface rather than permitting partial entry into the filter as in the case of dry grinding dusts which could be shaken out by the hand crank.

The result is that the light lint and dust which is not taken out of the air stream by the cyclone forms a mat on the under side of the filter. This mat is allowed to build up and in doing so automatically becomes a filter of its own, stopping additional dust and lint. When sufficient thickness of mat has been formed, the suction at the intake hood diminishes. This is evidence that the mat should be removed.

SYLVANIA INTRODUCES IMPROVED RECORDING DILATOMETER

Sylvania Electric Products, Inc., Electronics Division, 500 Fifth Avenue, New York, New York, has announced an improved automatic dilatometer for continuous recording of the thermal expansion and contraction of a wide range of materials including glass, ceramics, metals and plastics.

The equipment is designed to provide continuous graphic recording of the twelve-hour expansion and contraction cycles of samples. It eliminates tedious plotting of instant values and permits determination of true variations in length even when samples exhibit exceptions to the rule of elongation as a function of temperature.

The instrument is fully enclosed in a steel cabinet permitting ready access for setup of specimens. Recording meter and other instruments are flush-mounted permitting visual indication of operating temperatures and the progress of thermal expansion curve plotting elongation against temperature.

The dilatometer includes a furnace or sub-zero cooling chambers; furnace thermocouple; concentric quartz tube; specimen thermocouple; gearbox and support; transmission; contact mechanism; electronic relay; and recorder. Each one of these principal units performs a separate function but all functions are closely coordinated to hold specimen temperature uniform within 1° C.; provide uniform heating and

cooling with the specimen in an inert atmosphere; automatic shut-off; and an overall accuracy of 0.2 per cent.

Accommodating three, four or five inch specimens, the dilatometer will accommodate temperatures up to 1000° C.; weighs 450 pounds; and measures 56″ wide, 50″ high and 26″ deep. It is designed for use at 110-120 volts, 50-60 cycle supply and is rated at 900-1000 watts.

NEW GAS-MEASURING INSTRUMENT

Mine Safety Appliances Company, Pittsburgh, Pa., has added to its line of precision gas-detecting and measuring instruments the M.S.A. Oxygen Indicator Type C. The indicator measures the oxygen content of gaseous mixtures in chemical, metallurgical, petroleum and allied industries, and is used for combustion and process control and for improving the safety of utility operations and controlling pipe line corrosion.

The most important feature of the new indicator is its electrolytic detector cell. This is made up of a plastic container with a hollow carbon tube and metallic plate serving as electrodes in approximately an ounce of liquid electrolyte. Polarization in the cell causes hydrogen to be deposited on the carbon pole. When a gas sample containing oxygen is passed through the hollow carbon electrode, diffusion through the porous carbon causes the oxygen to combine with the "electrolytic hydrogen" reducing the internal resistance of the cell and causing its current and voltage output to be increased. A direct reading meter, having a linear scale, indicates the percentage of oxygen in the sample.

CATALOGUES RECEIVED

The Clipper Manufacturing Company, 2800 Warwick, Kansas City 8, Missouri, has published a bulletin, No. 70, describing Clipper superior blades for cutting brick, tile, refractories, stone, etc.

The colorfully illustrated folder describes the varying material densities and gives the reason why different materials require different Clipper blades. Microscopic enlargements of different brick bodies are pictured, together with information about cutting glazed tile, chrome and magnesite, or concrete with different aggregate.

Acheson Colloids Corporation, Port Huron, Michigan, has released a technical booklet on colloidal graphite and its uses in lubrication, parting, surface coating, impregnation, etc.

The 16-page booklet presents five extended specification tables regarding dispersions in water, oil, hydrocarbons, alcohol and special organics, and over 25 illustrations of applications. Interpretations of the 19 fundamental properties of colloidal graphite are given and photomicrographs of the material. Complete reference and indexing to 12 specialized technical bulletins, 6 published reports and 5 pieces of application literature are also included.

In the glass and chemical industries, such applications as the impregnation of plastics and the lubrication of glass molds have constituted important usages of colloidal graphite dispersions.

The Blanchard Machine Company, 64 State Street, Cambridge 39, Mass., has recently issued three catalogues relating to the company's grinders.

The first booklet, entitled "Work Done on the Blanchard," presents typical examples of the machining and finishing of flat surfaces by Blanchard grinding. Applications and versatility of Blanchard grinders are shown throughout the booklet and wheel data is given. The booklet illustrates the various grinders and grinding accessories, giving descriptive information about each.

Booklet 18 describes and illustrates No. 18 Grinder. Front and rear views are presented and the operation, wheel, wheel dresser, spindle, direct motor drive, wheel head, column, alignment, base, feed, lubrication, etc., are discussed. Specifications are given and diagrams of the machine, chuck and guards are included.

The third booklet, No. 11, presents the same descriptive material for the No. 11 Grinder as for the No. 18.

The Bristol Company, Waterbury 91, Conn., has announced a new bulletin, No. S1400, which describes its line of Tachometer Recorders and Indicators.

The twelve-page bulletin includes a complete description of the Pyromaster potentiometer-type tachometer, together with a description of the millivoltmeter-type indicating and strip-chart recording tachometers.

Complete wiring diagrams, application data, accessory information of instruments, magnetos and a typical installation are given.

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FERRO CHEMICAL CORPORATION now provides a *single source of supply* for Industrial Chemicals, Metallic Driers and Fungicides—as well as a continuation of the same fine service you have come to expect from the original organizations.

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Distributors for Aluminum Ore Co.; American Potash & Chemical Corp. (Borax and Boric Acid); Darling & Co. (Oleic and Stearic Acids); Duquesne Smelting Corp. (Nonferrous Metals, Zinc Dust); Ferro Drier & Chemical Co. (Driers and Metallic Soaps); Lindsay Light & Chemical Co.; Merck & Co. (Laboratory Reagent Chemicals); Philadelphia Quartz Co. (Silicates); Stauffer Chemical Co. (Sulphur); Tennessee Corp.; Virginia-Carolina Chemical Co.; Wyandotte Chemicals Corp.; and others.

CURRENT STATISTICS . . .

(*Continued from page* 509)

July. At the close of August 1945, inventories were 3,800,906 gross.

Plate glass production, according to the Hughes Statistical Bureau, dropped about 9 per cent to 16,802,955 sq. ft. produced during August. Production during July was 18,408,556 sq. ft. During August 1945, 8,965,701 sq. ft. of plate glass was produced which is just about half that produced during August this year. Total production for the first eight months of 1946 is 126,401,588 sq. ft., as compared with 65,927,623 sq. ft. produced during the corresponding period last year.

Automatic tumbler production for the month of August 1946 dropped about 34 per cent to a figure of 7,891,004 dozens. The previous month, production had been reported at 11,966,205 dozens. During August 1945, production reached a total of 5,865,374 dozens. Shipments for August 1946 showed an increase of about 32 per cent and were reported to be 7,946,335 dozens in comparison with 5,984,036 dozens shipped during July. During the month of August 1945, shipments were reported to be 5,883,791 dozens. Stocks on hand at the close of August 1946 were 10,399,207, in comparison with 10,609,145 dozens at the end of July. Stocks at the end of August 1945 were 4,461,051 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of August 1946 were 4,334,632 dozens. This represents about 22 per cent more than the 3,553,057 dozens reported for July. Sales for August 1945 were 3,474,018 dozens. Total sales during the 12-month period ending with August 1946 were 44,726,449 dozens.

RESEARCH DIGEST . . .

(*Continued from page* 508)

achieved in a glass is a reflection of the complete past history of preparation of the glass. By understanding and controlling more closely the separate events in this past history, better processing quite probably can be achieved."

WICKWIRE MOVES GENERAL SALES OFFICE

In a move to bring top sales and production department officials into one location for better coordination and efficiency, Wickwire Spencer Steel Division of the Colorado Fuel and Iron Corporation has moved its General Sales Manager's office from New York City to 361 Delaware Avenue, Buffalo 2, New York.

Involved in the move were A. G. Bussman, Vice President in Charge of Sales; H. C. Allington, Assistant General Sales Manager; The Wire Department General Office under C. G. Matthews; Market Research Department under Henry Davis; and the Advertising Department under S. E. McCrum. The Wire Rope Department under A. S. Rairden has been transferred to the plant at Palmer, Mass.

It was also announced by the company that Percy Jenkins has been appointed Eastern District Sales Manager with offices in New York City. The New York City Sales Office will now be known as the Eastern District Sales Office.

TOLEDO GLASS MEN AWARDED MEDAL FOR MERIT

William E. Levis, Chairman of the Board of Owens-Illinois Glass Company, John D. Biggers, President of Libbey-Owens-Ford Glass Company and Harold Boeschenstein, President of Owens-Corning Fiberglas Corporation, have been awarded the Medal of Merit for "exceptionally meritorious conduct in the performance of outstanding services."

The three glass men were among 15 civilians receiving the medal, which can only be awarded by the President. Messrs. Levis, Biggers and Boeschenstein served on the War Production Board and its predecessor, Office of Production Management, on separate assignments.

Mr. Levis started his career in the glass business working with the former Illinois Glass Company. He eventually became Vice President and General Manager of the firm and when it was merged with the Owens Bottle Company in 1929, he became Vice President and General Manager of the newly formed Owens-Illinois Glass Company. The following year he was named President. Several years ago, he was elevated to the Chairmanship of the Board of Directors.

In 1914, Mr. Biggers became Assistant Treasurer of the Owens Bottle Machine Co., following several years in advertising work. After successive promotions, he became Vice President of Owens Bottle Company. In 1926, he left the glass industry to become Managing Director of Dodge Brothers Britain, Ltd., in London, returned later to be Vice President of Graham Brothers Corporation and, in 1930, was elected President of Libbey-Owens-Ford Glass Company.

Harold Boeschenstein entered the glass business in 1921 following several years in banking. He has been President and a Director of Owens-Corning Fiberglas Corporation since the organization of the company in 1938. His first association with the glass industry was with the Illinois Glass Company and affiliates. After the Illinois Glass and Owens Bottle merger into the Owens-Illinois Glass Company in 1929, he became Vice President and General Sales Manager of the new company and later, Vice President and General Manager.

ACS SECTION TO HONOR DR. TURNER

The Northwest Ohio Section of the American Ceramic Society will honor Dr. W. E. S. Turner, a professor emeritus of Sheffield University, England, at a dinner to be held in the Commodore Perry Hotel, Toledo, Ohio, on October 8. Dr. Turner and his wife have been visiting glass plants in this country.

An address, which is expected to attract many glass technologists in the United States, will be given by Dr. Turner. His subject will be, "Recent Developments on Tank Melting Furnaces."

Dr. Turner is President of the International Glass Commission and an honorary member of the American Ceramic Society.

• The Radiant Glass Company, Fort Smith, Arkansas, has filed articles of incorporation listing $25,000 authorized capital stock. Incorporators are George D. Carney, Resident Agent, J. S. Daily and Marguerite Brun Carney.

DR. S. R. SCHOLES NAMED DEAN OF COLLEGE OF CERAMICS AT ALFRED

Dr. Samuel R. Scholes, head of the department of glass technology since 1932, has been named Dean of the New York State College of Ceramics at Alfred University to succeed the late Dean Major E. Holmes.

Dean Scholes' appointment was announced by the office of President J. E. Walters following action by the Board of Managers of the College. The appointment is for one year as requested by Dr. Scholes. He will assume his new duties immediately.

Dean Scholes is regarded as one of the foremost authorities on glass in the country today. He was one of the charter Fellows of the American Ceramic Society named in 1931. He is also a Fellow of the Society of Glass Technology, Sheffield, England. He served as Dean of the A.C.S. Fellows in 1939.

Dean Scholes has served as Secretary of the Glass Division of the A.C.S. since 1935. A member of Keramos, he has served as its Grand Treasurer since 1933, succeeding the late Dr. Charles F. Binns in that capacity. He is Secretary of Committee C-14 on Glass and Glass Products for the American Society for Testing Materials and also serves as a consultant for several glass manufacturers.

Many papers on glass have been written by him. He has edited several books on glass and has written the annual paragraph on glass in the Encyclopaedia Brittannica for the past seven years. He is listed in Who's Who in America.

Dean Scholes, 62 years old, was born in Green Lake County, Wisconsin. He received his B.A. at Ripon College in 1905 and earned his Ph.D. at Yale University. Prior to coming to Alfred, he had worked with glass concerns in Pennsylvania, Maryland, West Virginia and Ohio.

N. Y. METROPOLITAN SECTION SCHEDULES FALL MEETING

The New York Metropolitan Section of the American Ceramic Society has announced its plans to hold a dinner meeting on October 30. The meeting will be held in the Building Trades and Employers Association Building in New York City.

On the program for the evening is a talk by George Morse of U. S. Gypsum Company, "New Developments in Gypsum Cement". Mr. Morse will also present a sound slide account, "Making Tomorrow's Pattern".

AGA CONVENTION PLANNED

The American Gas Association will hold its twenty-eighth annual convention in Atlantic City the week of October 7.

Advance registration indicates an attendance of nearly 10,000 and it is expected that the convention will be the largest and most significant ever held in the gas industry.

FEATURES OF THE H-E BATCH CHARGING SYSTEM

- More glass can be melted
- Improvement in glass quality
- Longer life for checkers and furnace structure
- Batch is fritted-over before entering melting chamber
- Reliable operation — rugged construction
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H-E AUTOMATIC BATCH CHARGING GIVES PLANNED DISTRIBUTION

IMPROVED GLASS QUALITY and increased production result from the use of the Hartford-Empire Batch Charging System. This system, engineered as a part of the glass melting furnace, delivers, meters, and introduces batch into the melting area. It provides planned batch distribution in measured amounts at any desired charging cycle.

The movement of batch from the charger into the furnace is accomplished by an oscillating pusher, protected against damage from obstructions in the batch by an ingenious spring mechanism. Complete with timer, switches, indicating lamps, etc., the control panel automatically produces any desired cycle of operation in batch distribution. A glass level gauge, mounted on one of the forehearths, permits readings to within 1/64", plus or minus.

The Hartford-Empire Batch Charging System is the answer to today's competitive need for greater efficiency in glassmaking. For personal guidance from Hartford engineers in assessing the particular requirements of your operation, write the Hartford-Empire Company, Hartford 1, Connecticut.

Single Batch Charger installation. Double Charger is shown on opposite page.

Write for illustrated folder on the H-E Batch Charging System.

HARTFORD-EMPIRE COMPANY
HARTFORD 1, CONNECTICUT

(*Continued from page* 499)

formed rods in air and the selection of samples for the density determination from certain size limits of the drawn and quenched rod. Samples obtained in this manner have a similar thermal history and thereby eliminated the need of reannealing. The use of such rod samples for density control work was recommended for the following reasons: 1) the elapsed time between the time the batch enters the furnace and the completion of the density determinations on the resulting glass is about three to four hours less than when lehr-annealed bottle samples are used and about six to seven hours less than when reannealed bottle samples are used; 2) rod samples show less variability in the effect of thermal history on density than samples taken from lehr-annealed bottles from a number of lehrs; and 3) rod samples are always available regardless of whether finished ware is being produced. It was shown that by adding —4.0° C. to the figure obtained for the rod samples, they will be corrected to the lehr-annealed value.

While Duff's technique showed the plant technologist how he could save several hours time in the study of "effect and cause," this amount of time saving was evidently not enough to satisfy the desires of the co-authors of the next paper in the symposium who were Messrs. W. H. Manring and D. E. Waid of Ball Brothers Company. These gentlemen were truly working with "yesterday's batch, today's data and tomorrow's correction."

The title of their paper, "Dog-house Sampling Techniques and a Method of Estimating Day to Day Changes in the Working Properties of the Glass," meant just what it said. The sampling technique employed by Manring and Waid consisted of plunging a sampling mold and rod down to a depth of about 4 to 8 in. below the glass level in the doghouse, cracking out the sample after the mold was withdrawn from the doghouse and allowing the sample to cool for a standard length of time in an asbestos cooling box. Daily densities on the doghouse samples and lehr-annealed samples showed that the doghouse samples followed the same changes as the lehr-annealed samples when plotted graphically, but that the lehr-annealed samples had a time lag of about 18 to 24 hours. The doghouse sampling technique, in the opinion of the speakers, therefore successfully predicted the glass density at the feeder at least 18 to 24 hours in advance.

Not content with this achievement, the authors attempted to put this advance knowledge to practical use. "If," they stated, "we know as of today what tomorrow's density at the machine will be, what can we do with this knowledge?" Using a soda-calcia-silica triaxial diagram, they plotted lines of equal density. Along with their density determination, they then made a soda determination on the doghouse sample. (A sodium oxide determination, using hydrofluoric-perchloric acid solution and evaporation and the triple acetate separation, can be made both quickly and accurately.) Knowing both the density and the soda content of the doghouse sample, the other two ingredients, i.e., silica and calcia, can then be read from the composition lines of equal density triaxial diagram. A second triaxial diagram was then prepared to take care of the relationship between composition and viscosity. (This was based on Morey's work.) Instead of lines of equal viscosity, lines of temperature difference (based on the standard composition, density and viscosity) were plotted. By use of this diagram (which is based on soda content, density-composition and temperature-viscosity differences), it then becomes possible by the doghouse sampling technique to determine in advance the temperature adjustments that must be made at the feeder.

Discussion of this technique by several technologists during Session Q led to the conclusion that it suffered from over-simplification as the effect of minor ingredients on properties, such as density and viscosity, are not taken into account by these triaxial diagrams. It was the consensus of opinion, however, that Messrs. Manring and Waid should be highly complimented on their attempt to put density determinations to a practical production use.

Some of the discussion after the doghouse sampling paper dealt with the question of what happens when the sampling mold is thrust into the glass. Several technologists indicated that it was highly probable that top glass was carried down to the 4-8 in. sampling level. By coincidence, the next speaker gave the solution to this problem when he discussed the sampling procedure used in his investigation.

F. L. Bishop, Jr. and James M. Staples, of the American Window Glass Company, in their paper, "Furnace Density Surveys," departed from the usual use of glass density determinations. Instead of using density as a control tool, Bishop and Staples used density as a research tool in the investigation of glass flow in the furnace.

By using a sampling gadget consisting of two heavy steel hemispheres mounted on a rod and controlled by levers so that they would form a sphere when the two halves were closed, they were able to sample glass in the furnace from the surface and to various depths including the furnace floor. The method of using this sampling gadget consisted of introducing it, with the mold closed, through a furnace opening and, by means of the rod length and sampling angle, take samples from the glass surface, 1′, 2′, 3′ and 4′ below the surface, and bottom glass by simply opening the mold and allowing the glass to fill it. The closed mold was then withdrawn from the glass and furnace. It was then quenched in water, the excess glass cracked off and the sample removed from the mold. All samples were then annealed, using a standard annealing schedule. Samples of glass from production were also taken. The density of these daily samples (both furnace and production) were then measured and plotted.

An analysis of the graph of the furnace investigated disclosed that all samples, regardless of depth, showed the same trends; in fact, the bottom glass seemed to show the trend quicker than the surface glass. No large differences in density were found between the five samples from the furnace. It was concluded that, for the particular furnace investigated, there was a lack of streamlined flow and that the entire mass of glass in the

(*Continued on page* 520)

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YOUR APPROX. PROFIT $22.03

Our Retail Selling Price **$35.00**

RAILROADS STUDY BONDED-BLOCK METHOD . . .

(*Continued from page* 505)

This tilting often occurs in carload shipments, especially when lengthwise slack develops in the load. When this happens the horizontal edges of the tilting boxes dig into the sides of adjacent boxes smashing and cracking the contents.

Copies of this pamphlet—No. 13—may be obtained by writing to the Executive Vice-Chairman, Operating-Transportation Division, Association of American Railroads, 59 East Van Buren Street, Chicago, Illinois.

Not long after the bonded-block method of rail shipment loading had been evolved, glued loads appeared on the transportation scene.

In this system, the cartons are held in place by a special type of adhesive with a high shear strength but a low tensile strength. The high shear holding power prevents the dislodging of containers by lateral force while the low tensile strength permits easy separation, when desired, by a sharp upward pull or thrust.

Glued loading entered the experimental stage a little more than three years ago when the Bureau of Supplies and Accounts of the United States Navy tried loading shipments of containers between which had been applied small amounts of glue.

It wasn't long before industry became interested. The Association of American Railroads ascertained that by the application of a proper adhesive to a bonded-block pattern of cartons of a given size the holding forces were increased from 167 per cent to 500 per cent of the original force.

Reports received on test carloads have shown consistently good results.

For instance, one large shipper of liquor found that out of seven carloads of glued containers there was a total of only six bottles broken, two of which were evidently weak, defective bottles. At a later date, the same shipper reported that of 12 carloads shipped there wasn't a single broken bottle.

Of course all reports aren't that rosy. There have been carloads which suffered considerable damage, but in every instance the cause was analyzed as due to improper loading.

Examining the bottom of a fibreboard carton which has had two strips of glue applied is A. W. Godfrey, Office Manager of California Associated Products Company. The applicator features the two large wheels in the foreground which rotate in a tank of glue and apply the mucilage to the underside of the boxes as they pass over.

A number of methods of gluing cartons have been tried out, but the best system devised to date calls for a small metal glue pan within which are two metal rollers.

This glue pan is inserted in a conveyor system, usually near the end of the conveyor where it extends into the box car being loaded. As the box moves down the conveyor it passes over the glue rollers which paint two narrow strips (⅝ inch wide) of glue to the bottom of the box. At the end of the conveyor the box is picked up by a loader who places it in position and it becomes glued to the box upon which it rests.

The glue rollers are adjustable to accommodate various size containers and provision is made so that all excess glue is scraped off them. The glue strips should be placed approximately two inches in from each side of the box.

As for the glue itself, it must be designed specifically for the purpose of binding containers together for rail shipment. The specifications to be met call for the glue to set in approximately five minutes, to adhere to the container to which applied and to the container underneath, and to permit the separation of the containers without disfiguring or tearing the fibre tissues of the box.

The Freight Loading and Container Section of the Association of American Railroads has discovered that the one serious obstacle to the completely satisfactory use of glued loads is this problem of separating the containers without marring their surfaces. Actually, these tear marks along the glue lines do not appear to affect the physical strength of the containers, but it does mar the appearance of the carton from a commercial merchandising viewpoint.

However, glue and container manufacturers are burning the midnight oil over this difficulty and it is expected that the near future will see it corrected.

Of course it mustn't be expected that new loading methods will compensate for the use of inferior cartons.

(*Continued on page* 528)

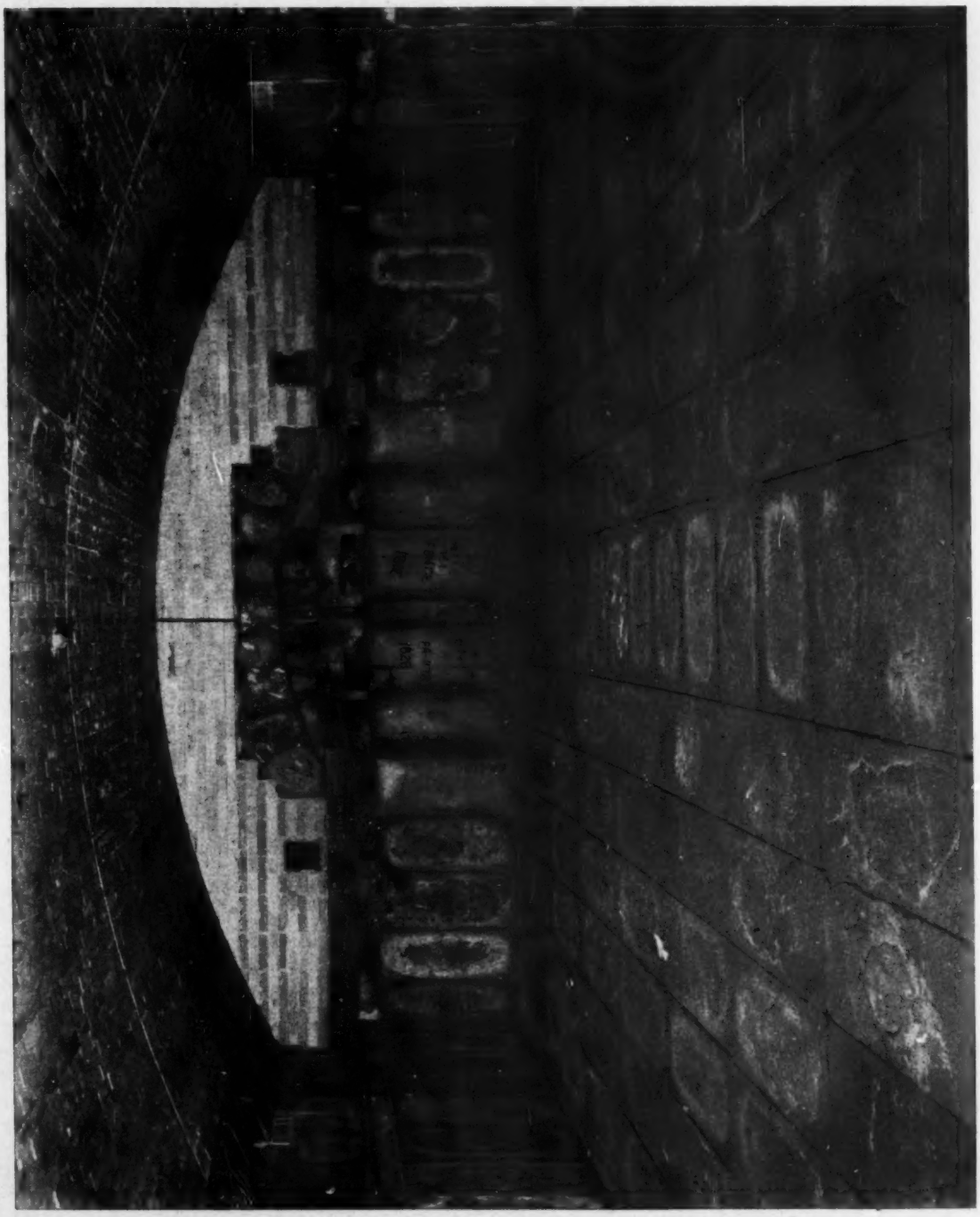
Passing along the conveyor and over the glue-applying wheels at the end of the carrier are fibreboard cartons of the California Associated Products Company. The boxes are then stacked as usual in the box car and the quick drying glue binds them together into a damage-resistant unit.

ANOTHER CORHART* ELECTROCAST BOTTOM

in a clear-flint bottle glass furnace. This customer has been using Corhart* Electrocast in bottoms for twelve years.

Corhart Refractories Company, *Incorporated,* Sixteenth and Lee Streets, Louisville 10, Ky.

*Not a product, but a registered trade-mark.



COLUMBUS DISCOVERS GLASS . . .
(*Continued from page* 516)

furnace was acting as a unit. In other words, the incoming batch seemed to push out an equal amount of glass at the working end. (An analogy would be a soft drink filling line—as fast as one bottle leaves the line, another is placed at the beginning of the line and every bottle in the line moves up a space.)

In the discussion that followed, Bishop referred to this furnace as a "slow furnace". Others that he has investigated by the cerium technique being know as "fast furnaces" inasmuch as changes in composition are noted in as low a time as five hours.

In discussing the merits of "fast" versus "slow" furnaces, Bishop stated that, from his experience, when you get in trouble with a "fast" furnace, only a few hours are required before the trouble clears up, but that in the case of the "slow" furnace, when you get in trouble, you are in trouble for several days. It was also brought out that experiments of this type can only be made when the composition is changing and in this particular type of operation, composition changes are not desirable.

In the last paper presented in this symposium, A. L. Bracken, Jr., and A. G. Allen (Hartford-Empire Company) discussed the time interval in sampling of glass for density. Bracken stated that before a control chart is set up, all the feeders on the furnace should be sampled and their densities determined. If this procedure is followed for a few weeks, the feeder most sensitive to change may be readily found. In most cases, this is usually the feeder carrying the heaviest load.

Bracken's procedure in setting up a density control chart is, in brief, as follows: samples from the same feeder are taken at two hour intervals until five samples have been obtained (total time is, therefore, eight hours). The five samples are then run as a unit and the average density and range obtained. By the use of probability limits, as recommended by Simon, upper and lower limits based on range are then calculated.

This procedure is somewhat different than Ghering's 3-day range procedure in which a slightly different statistical method is used. The discussion centered around statistical procedures and became somewhat involved.

Symposium on Glass-to-Metal Seals

The symposium on glass-to-metal seals was the first ever conducted by the Glass Division. About seventy-five members of the division attended the session. The meeting was capably conducted by Mr. Earl E. Beeton of the Western Electric Co., who explained that the symposium was the outgrowth of informal discussions by members of the Metropolitan New York Section of the American Ceramic Society.

Mr. Beeton, who served as group leader on tungsten seals, presented unpublished results of X-ray studies of tungsten oxides in seals, which showed that the final product of the chemical reactions is almost wholly tungsten dioxide. The discrepancy in color is due possibly to formation of a tungsten bronze. This theory is supported by the fact that glasses containing potassium as the alkali do not produce a seal of the same color as a glass with sodium as the alkali. In opposition to the tungsten bronze theory is the evidence that alkali-free glasses produce seals with the same color as those made with sodium-containing glasses.

Mr. Stanton Umbreit of the Radio Corporation of America pointed out that molybdenum is not used extensively because it has few advantages over tungsten and suffers from a tendency to over-oxidation, with consequent leakage. Mr. Umbreit also reported on the use of steel for hermetic seals, both internal seals which require a match in the expansions of glass and metal and external seals in which the metal has a considerably higher expansion than the glass. Unplated SAE 1010 steel is used in the latter manner for button stems which constitute the lead-through portion of metal radio tubes. The steel in this case has replaced the 28 per cent chrome iron formerly considered necessary because of its close match to the expansion of the glass used.

Kovar, an iron-nickel-cobalt alloy, was discussed in detail by Mr. Joseph A. Pask of the Westinghouse Electric Corporation, Lamp Division. Methods of making seals were described, and measurements on proper oxidation of the alloy prior to sealing showed that best results were obtained with an oxide thickness between the limits of 0.0003 and 0.0007 grams per square centimeter of surface. An interesting point brought out by Mr. Pask was the indication, on the basis of preliminary X-ray studies, that the oxide in a Kovar-glass seal is chiefly magnetite, Fe_3O_4.

Mr. H. K. Richardson of the Westinghouse Electric Corporation, Lamp Division, outlined the development of copper-glass seals by W. G. Housekeeper, and explained the method used by Westinghouse to produce an inside-outside thin-edge tubular seal. Discussion from the floor showed that thin-edge copper disc seals have been used to some extent in specialized devices.

The manufacture of Dumet (copper-clad nickel iron) was described by Mr. C. D. Spencer of the General Electric Company. The considerable difference between radial and longitudinal expansions of Dumet prevent its use in diameters greater than 0.040 inch in seals. The color of the borated Dumet does not appear to be critical in terms of a finished seal. Unborated Dumet has been used successfully in seals.

Mr. Robert F. Doran of Sylvania Electric Products, Inc., discussed the use of 28 per cent chrome iron in seal making, and pointed out the special problems in connection with this alloy which led to the development of Sylvania No. 4 alloy (iron, nickel, and chromium). The matter of selective oxidation of the chromium was explained, and Mr. Doran stated that he had not been able to wet chromatic oxide (Cr_2O_3) with glass. This is contrary to usual experience, and, since the experiments were performed with a composite lead of nickel-plated and chromium-plated base metal, there is a strong possibility that leakage occurred between the sheaths of plating rather than along the glass-chromic oxide interface.

Ceramic-glass-metal seals of various types were shown and discussed by Dr. Louis Navias of the General Electric Co. Compositions of glasses and ceramics were given. All of these seals involved the use of metals or alloys, glasses, and ceramics which have essentially equal thermal expansions, at least in the critical range. In general, the glass merely served as a sealing medium

(*Continued on page* 528)

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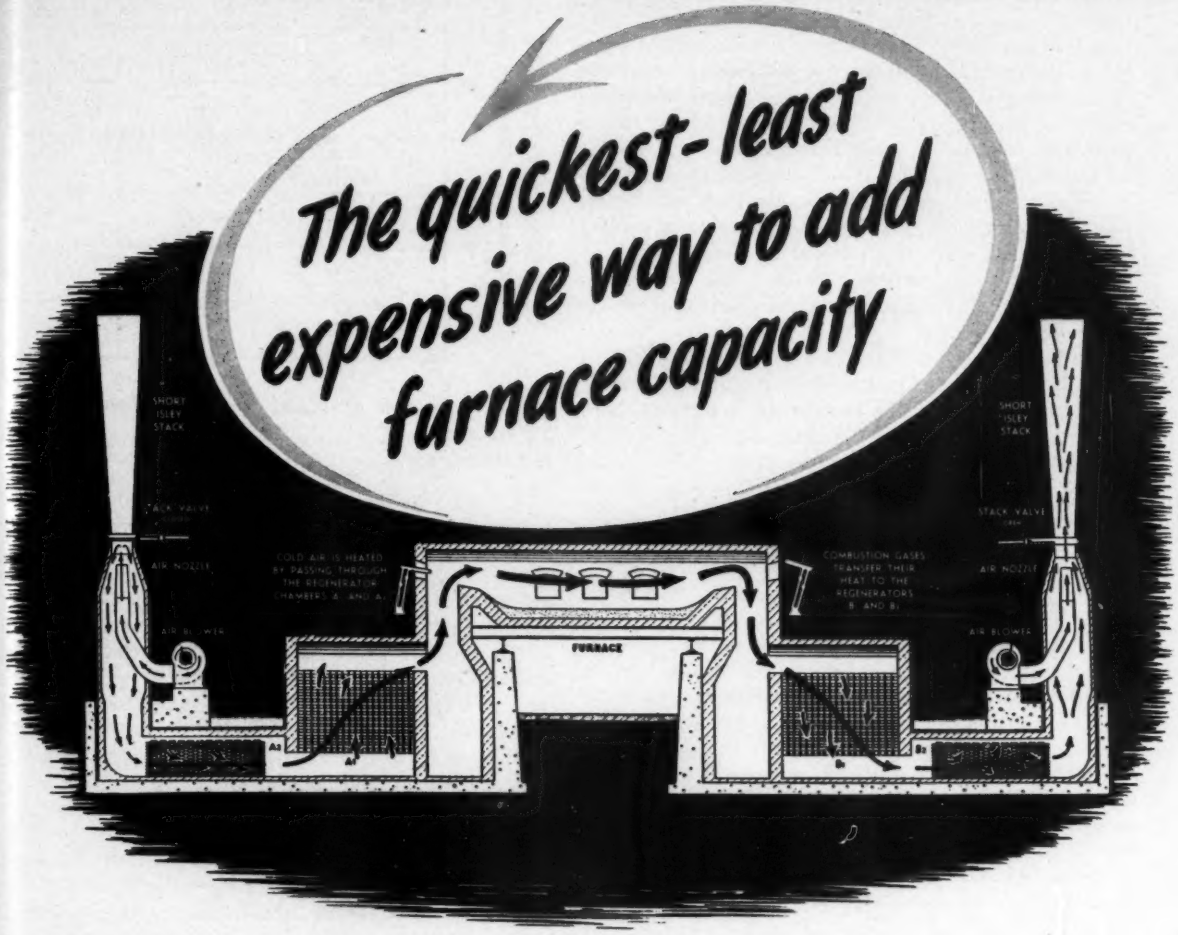
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(*Continued from page* 504)

to mean the difference between tensile and compressive stress.

(d) *Temperature of retention of strain.* All the equations for calculating stresses in a seal require knowledge of the temperature at which glass no longer yields viscously or plastically. This temperature will of course vary with the rate of heating and cooling. From the definition of strain point it would seem that this temperature could be taken. Glass, however, can retain strain above this temperature unless the rate of cooling is so slow that strains are relieved by viscous flow. By definition even the annealing point is not too high to permit retention of strain, and actual observation proves this to be the case.

Fig. 17a is a plot of tungsten-Nonex (Glass 772 in Table 2) seal observed in a polariscope furnace[43] during heating and cooling. The sample was a flat stem with two tungsten leads (about 0.040 in. diameter) and the stress observed was the axial stress at each wire. From Table 2 the strain point of 772 Glass is found to be 484° C., while the annealing point is 518° C. The rate of heating was slightly less than 2° C. per minute and the rate of cooling was slightly greater than 3° C. per minute. The axial stress before heating was a moderately high tension. At 525°, when the first observation was made, the compression developed on heating had almost entirely counteracted the original tension present along the wire, and at 536° the counteraction was complete. A gradually increasing compression now appeared, reached a maximum in the region of 580°, and then decreased as plastic flow and viscous flow began to relieve the stress. At 620° only a slight compression remained, at 632° merely a trace of strain, and at 635° viscous flow relieved stress as rapidly as produced. On cooling there was no definite evidence of the re-appearance of strain until a temperature of 608° was reached. With further cooling the stress due to differential contraction increased fairly rapidly.

It is evident from Fig. 17a that glass can retain stress at a temperature one hundred degrees above the annealing point, even with relatively slow heating and cooling. Fig. 17b shows that the "no strain" point drops slightly with prolonged heat treatment at high temperature. Before the final cooling, however, stress is retained at a temperature well above the annealing point. Only a long anneal at a fixed temperature would permit release of the strains produced even with slow cooling.

In view of the behavior just described it is extremely difficult to choose an upper temperature for use in computing δ. It can only be said that the closer the approach to equilibrium conditions the more accurate the result, and this conclusion is applicable to measurements of all properties of glasses.

Because of the uncertainties which are inherent in all methods of calculating stresses in a glass-metal seal the only reliable recourse is actual measurement of strain by photoelastic methods. Even this procedure is not free of problems. Because of the curved surface of a beaded lead and many types of seals, and surface irregularity of nearly all seals, an immersion cell[44, 45] is necessary for accurate results in many cases. Even after the retardation is measured[46] by means of color, quartz wedge, Babinet compensator, or other method the observed value is in general produced by two principal stresses at right angles to each other[47]. To separate these stresses usually requires a rather tedious graphical integration[48]. Fortunately, Poritsky[14] has been able to demonstrate that in a cylinder of any shape the retardation depends only upon the axial stress so long as there is symmetry about a middle plane perpendicular to the path of light. Because of this fact it is possible to pass polarized light through a beaded lead, flat stem, or other shape in a direction perpendicular to the axis of the wire or wires and thus measure the retardation due to axial stress only. The components of radial and tangential stresses in the seal have cancelled out. By means of the measured retardation, the photoelastic constant (see Table 4), and the thickness of the glass the axial stress may be computed[45]. Then by use of Equations (3), (4), and (5) or Fig. 18 the tangential and radial stresses can be calculated, remembering that axial and tangential are always one kind of stress while radial is the opposite.

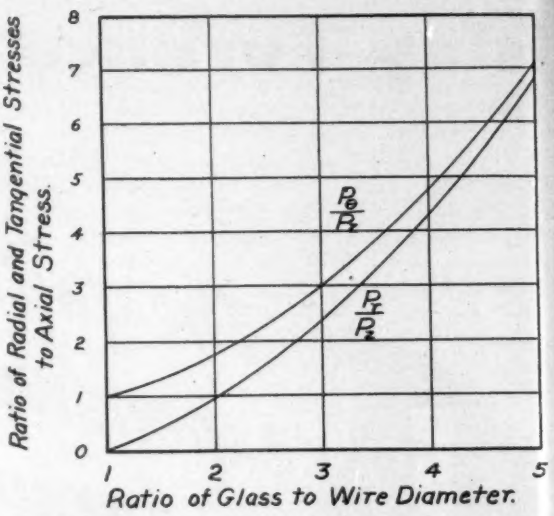


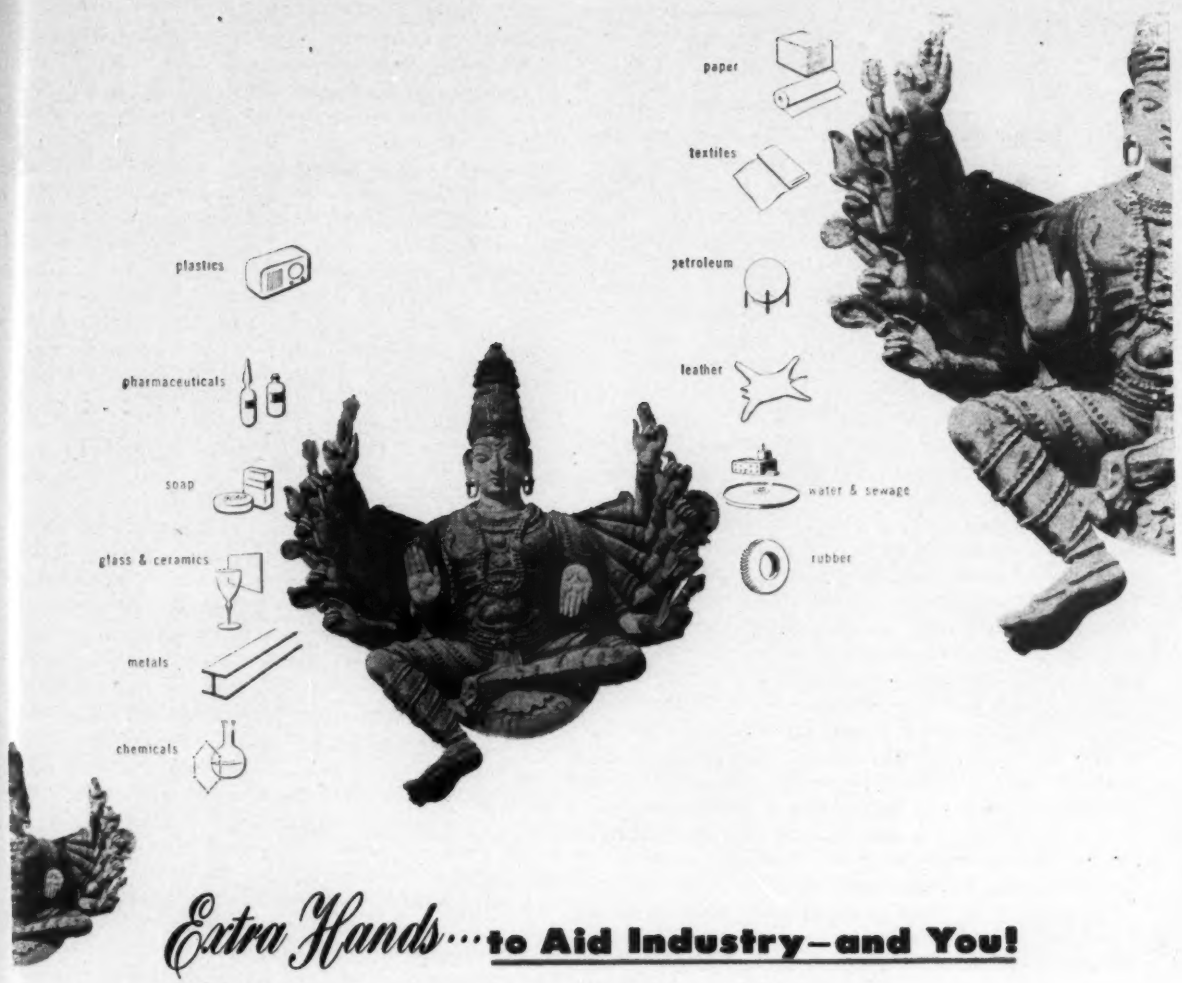
Fig. 18 Relationship between radial and tangential stresses and axial stress.

The equations and charts previously presented apply strictly of course only to a cylindrical beaded lead such as the one shown in Fig. 15. In practical application it has been found that no considerable error is introduced in the case of the ordinary internal seal if the glass diameter is taken as 2.5 times the wire diameter for purposes of computation provided Poritsky's stricture concerning symmetry is observed.

Difficulty is encountered if the equations and the relations between stresses are applied to a seal containing Dumet. The axial stress can be measured photoelastically. Because of the considerable difference between longitudinal and radial expansions of Dumet it is not possible to use Fig. 18 to determine the radial and tangential stresses from the measured axial stress. By substitution of the radial expansion of Dumet in Equa-

(*Continued on page* 524)

43. Monack, A. J., *Glass Ind.*, 19, 11-13 (1938).
44. Hull, A. W. and Burger, E. E., *Rev. Scientific Instru.*, 7, 98-100 (1936).
45. Becton, E. E., *Glass Ind.*, 19, 51-53 (1938).
46. Monack, A. J. and Becton, E. E., *Glass Ind.*, 20, 223-28 (1939).
47. Monack, A. J., *Glass Ind.*, 21, 513-14 (1940).
48. Monack, A. J. and Becton, E. E., *Glass Ind.*, 20, 277-82 (1939).



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Montreal • Toronto • Vancouver

(*Continued from page* 522)

tions (2), (3), and (4) the radial and tangential stresses can be computed. By substitution of the longitudinal expansion in Equations (2) and (5) the axial stress can be calculated. Ratios then can be set up as in Fig. 18. It is generally not necessary, however, to measure the radial and tangential stresses. Because of the great differential between the longitudinal expansion of Dumet and the expansion of soft glasses failure practically always results from axial tension. The radial tension is low in magnitude and tangential compression is not a source of difficulty.

A very complete analysis of stresses in a two-lead tungsten-glass stem has been made by Honigmann[49]. The importance of counterbalancing stresses caused by heating of wires through passage of current in a tube or lamp is emphasized.

Interpretation of strains in button, cup, and similar stems, such as those shown in Figs. 8b, d, e and 11b, c, is more difficult than the relatively simple cases of beaded lead and flattened stem. Nevertheless, proper approach to the problem may sometimes indicate a solution that is not too complex to be useful. An actual example will bring out the procedure.

The stem of the miniature tube shown in Fig. 8e is a small glass disc with several wires or leads perpendicular to the plane of the button. If the stem is well annealed there is little stress except that around each lead due to differential contraction of glass and metal. This strain occurs in a small cylinder of glass surrounding the lead. The diameter of the cylinder of strain is about 2.5 times the lead diameter.

The cylinder of strain in an annealed miniature stem is so small that the strain analysis is best made in an immersion cell under a petrographic microscope with crossed nicols at a magnification of about fifty times. A selenite plate is necessary to give color to the strained glass.

If the stem is examined edgewise the axial strain along the lead is a bluish green color equivalent to a retardation of 660 millimicrons. But the first-order red plate contributes 550 millimicrons. The difference is 110 millimicrons. Substitution of this value in the expression $S = R/0.1752\ C\ d$, where S is the unit stress in lbs. per square inch, R is the path-difference in millimicrons, C is the photoelastic constant in brewsters, and d is the thickness of the strain zone in inches, results in a calculated axial stress of 2130 lbs. per sq. in. compression. From Fig. 18 the tangential stress is $1.8 \times 2130 = 3830$ lbs. per sq. in. compression. The radial stress is 2130 lbs. per sq. in. tension.

This completes the determination of the values of the three stresses. A check is desired, however, on the accuracy and correctness of the results. With this view in mind the following procedure is followed.

The top view of the stem in the polarizing microscope shows a zone of strain around each lead. The color is highest near the lead, and the strain is such that the stresses are radial tension and tangential compression. This is determined by the colors in the four quadrants[50]. The algebraic sum of the retardations from these stresses is such that the color shows a path-difference of approximately 840 millimicrons.

The calculated value of radial tension, as computed from the edge view of the stem, is 2130 lbs. per sq. in. Substitution of this value for S in the previously used expression which relates stress, path-difference, and length of path results in a retardation of 110 millimicrons. Similar treatment of the tangential compression of 3830 lbs. per sq. in. results in a retardation of 199 millimicrons. Since the radial and tangential stresses are at rght angles and are opposite in kind, the retardations will add and the sum is 309 millimicrons. In two quadrants the path-difference of the selenite plate (550 millimicrons) adds to the path-difference of the glass, to result in a retardation of 859 millimicrons. In the other two quadrants the path-difference of the glass subtracts from the path-difference of the plate, to result in a retardation of 241 millimicrons. 859 millimicrons produces a yellowish green color; 241 millimicrons produces a yellowish white color. The top view of the stem in the immersion cell shows that two quadrants are yellowish green and the other two are yellowish white. The check is thus perfect.

If the disc itself in the above example is badly strained it is extremely difficult to separate these strains from the strains around the leads. Only a complete stress analysis with a graphical integration is reliable.

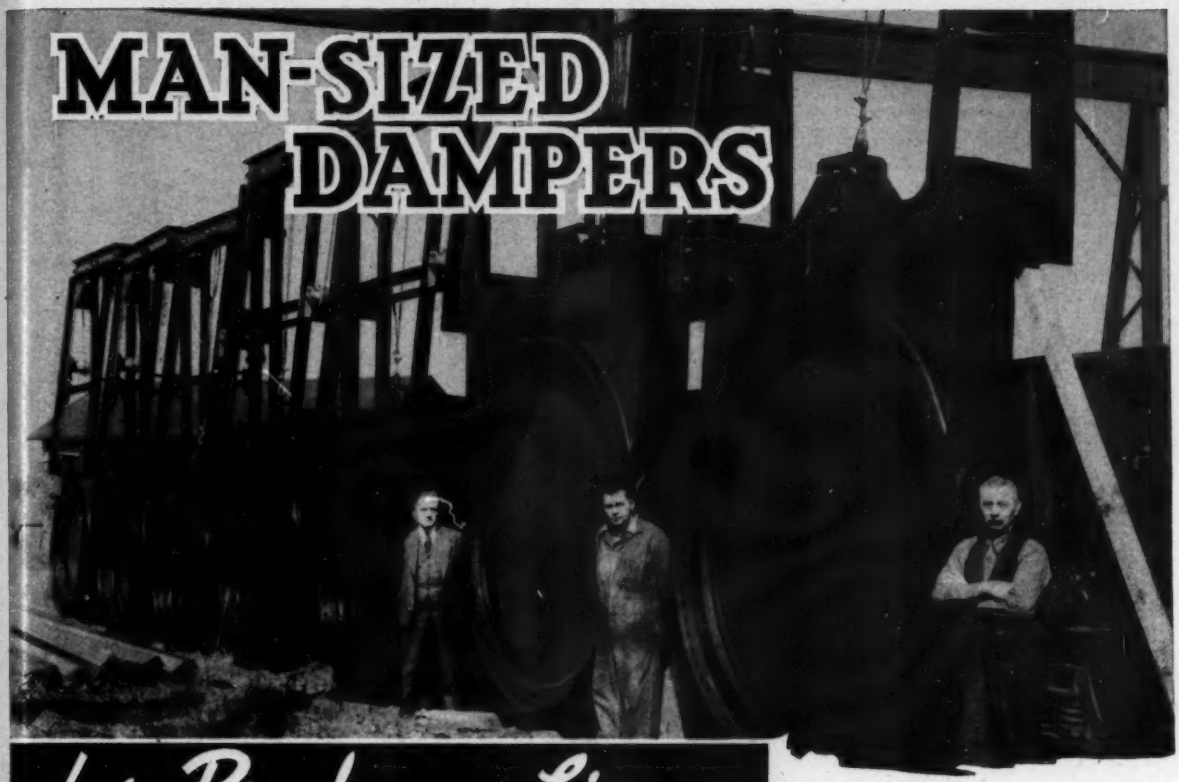
A complete analysis of stresses in the button stem used in metal tubes (Fig. 11b, c) has probably never been made because of the almost unbelievable complexity. In order to prevent "stripping" of the seal between glass and insert (the metal ring sealed to the outer edge of the glass button) during the operation of projection welding the stem into the metal shell or envelope, it is thought necessary to produce a strong radial compression in the glass next to the insert. It is quite likely that there is no need for production of this artificial stress when a metal with very high expansion, such as cold-rolled steel, is used for the insert. In usual practice, however, after the glass has been pressed into the insert a blast of air is blown on the bottom of the button to cause sudden cooling. After cooling has been initiated fires are brought to play on the metal insert, thus heating up the outermost portion of the button. The result at room temperature is a stress pattern of great complexity. The following explanation is indicative of the stress evolution in the stem.

If a small disc of glass in the plastic condition is cooled suddenly a temperature gradient results in the glass. The lowest temperature will be in the outermost ring of glass, and progression inward along a radius will show a gradually increasing temperature. The outermost ring will compress the ring next to it. The result will be radial compression and tangential compression at any point in the second ring, and radial compression and tangential tension in the outer ring. The second ring will in turn compress the third ring (resulting in radial compression and tangential compression in the third ring), and, in consequence, the stresses in the second ring caused by this action will be radial compression and tangential tension. At the same time, however, the tangential tension in the second ring will be counteracted partially by the tangential com-

(*Continued on page* 526)

49. Honigmann, L., *Glastech. Ber.*, **12**, 372-80 (1934).
50. Monack, A. J. and Beeton, E. E., *Glass Ind.*, **20**, 190 (1939).

MAN-SIZED DAMPERS



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(*Continued from page* 524)

pression caused by shrinkage in the outermost ring. This system of actions and reactions between adjacent rings will continue until a point is reached where the glass is no longer rigid enough to retain the imposed stress. From this point to the center the glass may be considered as a viscous liquid.

The glass in the outer portion of the disc does not of course exist as a series of discrete rings. The actions and reactions are continuous, instead of occurring in steps. The stresses set up in the outermost portion will be the greatest because the temperature in that portion will be lowest, and the stresses will decrease progressively as the point under consideration is moved inward along the radius to the portion of viscous glass.

The entire disc has been cooling. If this continued to room temperature the final tangential stress in the outer portion would be compression and the final radial stress would be tension. If, however, heat is applied to the outer edge before the inner portion has dropped below the temperature at which it will retain strain, continued cooling in the center portion will cause it to exert forces on the outer portion in such a direction as to produce tangential compression and radial tension. When the inner portion reaches room temperature (or any temperature at which the temperature gradient disappears) the outer portion will compress the inner, and the result will be tangential tension and radial compression in the outer portion.

In addition to the strain which varies radially because of the differential cooling, there is a variation in stress through the thickness of the button, resulting in a "sandwich" pattern which divides the button into three zones when viewed edgewise. Superimposed on the strains already mentioned are also those due to shrinkage of the metal insert upon the glass and those due to the presence of metal leads in the glass. Fig. 19a is a top view of a button stem, showing the isoclinics and the strain colors due to a tint plate. Fig. 19b is an edgewise representation of some of the stresses which cause the strain pattern shown in the top view.

Annealing Glass-Metal Seals

It can be shown theoretically that if a sample of hard glass 6 mm. thick is cooled from two sides at the rate of approximately 70° C. per minute from about 20° above the annealing point to about 20° below the strain point the residual stress should not exceed 0.2 kg/mm^2. With soft glasses the cooling through the annealing range should not be greater than 25° per minute if the same stress limit is not to be exceeded. Cooling rates such as these are not suitable when a metal is sealed into the same glass, and the usual conceptions of annealing must be modified somewhat when applied to seals. As a general rule, no attempt is made to obtain strain-free seals except in the few instances where the match between glass and metal makes this readily possible. In all other cases economic annealing requires only that stresses be reduced below dangerous limits.

Nearly all annealing of seals is a compromise. Thus, in the case of internal seals, because of the inherent

51. Littleton, J. T., *J. Amer. Ceram. Soc.*, 18, 239-45 (1935).

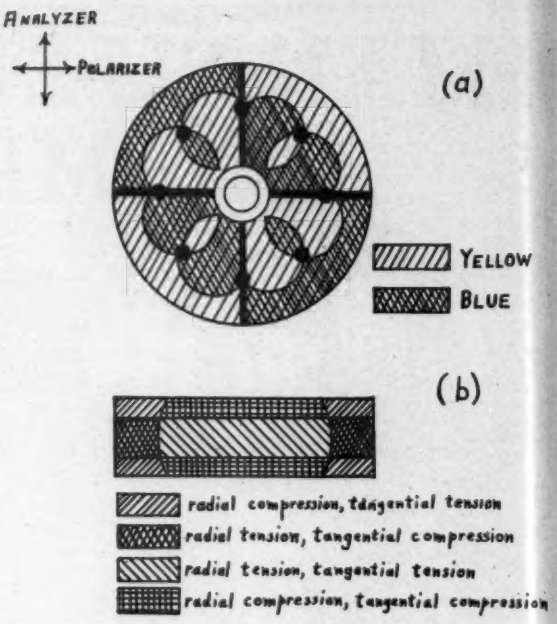

Fig. 19. (a) Diagrammatic representation of button stem strains as seen in the polariscope with tint plate; (b) cross-section to show partial distribution of stresses in the button stem.

relationship between the three principal stresses, while the advantages of radial compression are recognized it must always be remembered that the tangential stress will be tension and will be greater in magnitude than the radial stress. It does no good, therefore, to produce a high radial compression in order to prevent "stripped" seals if failure results through radial cracks caused by tangential tension. Conversely, strong tangential compression can mean failure through radial tension. The annealing must be a compromise in most cases between desirable compression and dangerous tension.

Nor can stress at room temperature always be taken as a safe criterion. Many electronic devices operate at temperatures well above room temperature, sometimes as high as 250-300° C., and the stresses set up because of differential expansion between glass and metal at the operating temperature may reinforce those already present and result in failure.

Again, as pointed out by Honigmann[49], passage of large currents through the leads may cause resistance heating of the metal. The stress thus produced may act to reinforce a dangerous stress already present.

Annealing, then, in the case of glass-metal seals must be designed for each particular application, with emphasis on the use to which the seal is to be put. The result will usually be a compromise. The procedures are simple. A long soak at the annealing point, or at the strain point, will produce glass in equilibrium at those temperatures. This will act to lower the expansion of the glass, which is desirable if the glass curve is above that of the metal. If the glass curve is below that of the metal at the annealing temperature fast cooling will tend to reduce the stresses at room temperature. In a tungsten seal with 772 glass it is possible to obtain axial tension with rapid cooling and axial compression

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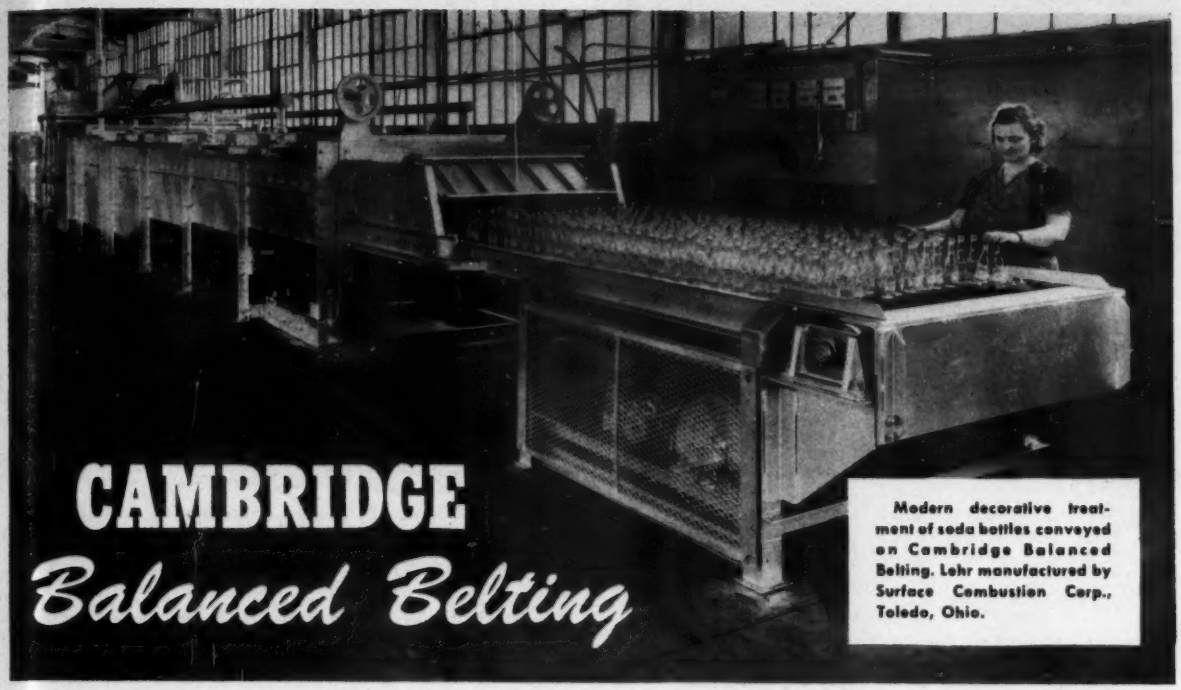

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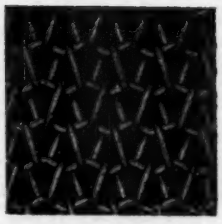

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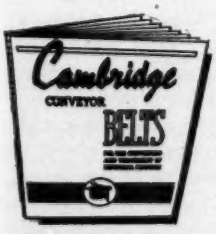

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GLASS-METAL SEALS . . .

(*Continued from page* 526)

with slow cooling or with long annealing at the strain point. In this case the glass curve at the annealing point is above that of the metal while at the strain point it is below the metal curve. The relative positions of glass and metal expansion curves will usually determine the annealing procedure. Littleton[51] has given the results of temperature treatment of several types of glass-metal seals, and he concludes that the amount and character of the strain can be controlled to an accurate degree by means of heat treatment.

Bahls, in his discussion[52] of the annealing of glass-metal seals, stated that the rate of relief of stresses is a function of the design constants of the structure, as well as the viscosity of the glass and relaxation characteristics of the metal.

Glass-Kovar seals may be annealed relatively strain-free if desired. This is generally not necessary. As in all cases of strain in glasses avoidance of sharply concentrated strain is more important than reduction of diffuse or broadly distributed strain of fairly high magnitude.

Thin-edge, disc, or ribbon seals employing copper always show strain of fairly high intensity corresponding to the stress required to cause yielding of the metal.

52. Bahls, W. E., *J. A. I. E. E.*, **57**, 573-78 (1938).

RAILROADS STUDY BONDED-BLOCK METHOD . . .

(*Continued from page* 518)

Weak containers are an open invitation to damage, a truth that was underscored in red during the preceding years of war and emergency.

With the nation's good packing materials going to the armed forces, it was necessary for shippers to rely upon inferior fibreboard to pack the goods destined for civilian consumption. At the same time, many skilled packers were drafted and the resultant tight labor market made it difficult to get even enough inexperienced workmen for replacements.

Today, however, the shipping department of the glassware producer is in a transitional period between the frugality of wartime economy and the comparative abundance of normal operation. With good packing materials becoming attainable and skilled workmen shedding their uniforms, shippers are approaching the day when they again are capable of adequate packaging.

This together with the development of glued loads and the bonded-block method, seem to be the answer to the damage bugaboo in the eyes of Association of American Railroads loading and container engineers and experimenting shippers.

COLUMBUS DISCOVERS GLASS . . .

(*Continued from page* 520)

between the ceramic and the metal, although in some instances glass was sealed to ceramic alone.

The symposium was concluded with a presentation by Mr. Ben J. Sweo of the Ferro Enamel Corporation of pertinent facts and theories relative to the adherence of porcelain enamels to metals.

(Continued from page 507)

so that when the work leaves the last burner, the glass is sufficiently soft for sealing or any desired operation. One disadvantage of these machines is that the work cools while passing from one station to the next. Also, considerable mechanism is required to provide for the rotary heads.

This invention improves the prior machines by providing a rotary table carrying a series of fixed heads and a burner for each head. The gradual heating of the work is accomplished by increasing the heat from the burners as they travel around the table. This is preferably done by increasing the gas pressure of each burner as it travels around with the table.

As shown in Fig. 3, a rotary table 1 carries twelve

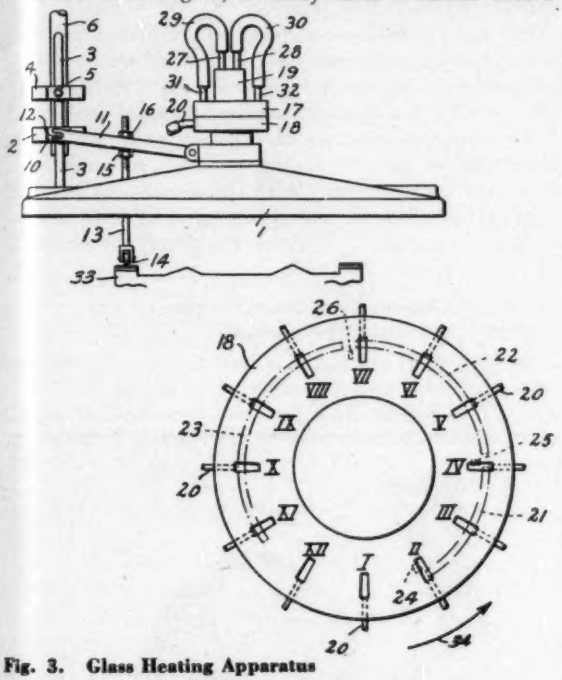


Fig. 3. Glass Heating Apparatus

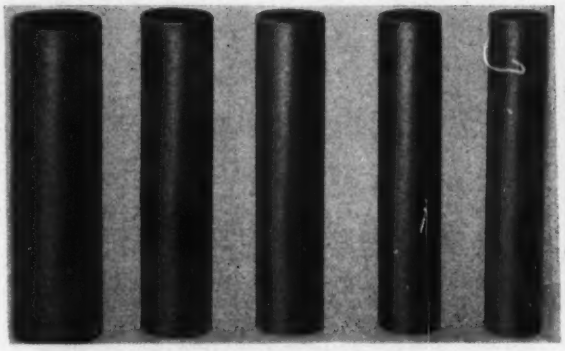
heads, only one of which is shown. Each head has a burner 2 movable vertically on guide rods 3 by means of a lever 11 actuated through a rod 13 and roll 14 by a fixed cam 33. This is for the purpose of giving the burner a slight vertical reciprocation in order to traverse the flame lengthwise of the work.

A holer 4 vertically adjustable on the rods 3 supports the work 6. The burner 2 is of the usual annular type having a large number of small nozzles directed toward the center. Gas is supplied to each burner through a flexible tube 20 under the control of a valve comprising a fixed disc 17 and a disc 18 which rotates with the table. Gas at different pressures is taken from the central column 19 and delivered to the fixed valve disc 17 through pipes 29 and 30 of which there are six in all.

The disc 18 has a series of ports each connected with one of the tubes 20 of which there are 12 as shown in the lower figure which is a plan view. The contacting face of the fixed disc 17 has six ports shown in dotted lines in the lower figure. As the disc 18 travels in the direction of the arrow, each port will be in successive

(Continued on page 532)

GUNITE
ROUND BAR STOCK



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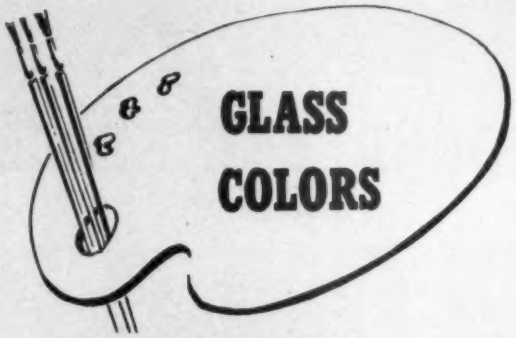

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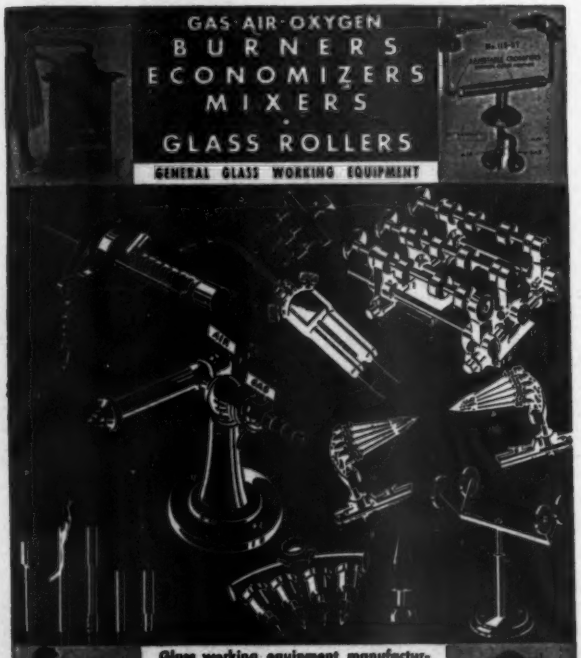

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COLOR AND SOLARIZATION OF GLASSES . . .

(*Continued from page* 501)

(about 250°C), whereupon the glass glows with a faint thermoluminescence. This fact gives rise to the question whether glass will be discolored by light if its temperature is raised above the temperature where luminescence ordinarily occurs.[4]

To answer this question, a small rectangular hot-plate was wound with cromel wire in such a fashion that a temperature gradient existed along the length of the hot-plate. Samples of glass were placed on the hot-plate in various temperature zones and exposed to ultraviolet light for 90 hours at a distance of 15 inches from the quartz-mercury lamp. The glass used for these tests was a manganese-arsenic glass with the base composition Na_2O 16.8%, CaO 8.5%, SiO_2 74.6%.

The tests yielded the unexpected result that an increase in temperature accelerated the rate of discoloration. Spectrophotometer curves showed increased fading up to 430°C, which was the maximum temperature used.

An interesting extension of this work would be the determination of the temperature necessary to cause these discolored samples to thermoluminesce. Also, the temperatures of exposure could be extended to the softening point of the glass. Time did not permit the performance of these additional tests.

Fading of Glasses Containing Ceria, Arsenic Acid and Cupric Oxide

In commercial practice it is known that some copper-bearing glasses[6] tend to change color markedly on exposure to sunlight. This fact was considered to be of

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sufficient interest to warrant a study of the fading of copper glasses in conjunction with two other oxides which are known to cause pronounced fading—namely, ceria and arsenic oxide. Therefore, a series of glasses containing small amounts of these oxides was prepared and exposed to ultraviolet light. The tendency to fade was very marked in most of the glasses. The changes in color were readily visible to the naked eye, and the effects so striking as to suggest the use of some of these glasses for measurement of sunlight intensity. Changes from faint blue to yellow in a glass containing ¼% ceria + ¼% copper oxide, and from blue to green (⅛% CuO + ⅜% As_2O_3) were notable. Additional work will be necessary to determine the optimum proportions and amounts of the various oxides for maximum fading tendency. It is probable that these color changes are associated with the following reactions which may occur in glass under the influence of light.

$$2\ Ce^{3+} + As^{5+} \text{ yields } 2Ce^{4+} + As^{3+}$$
(colorless) (yellow)

$$2\ Cu^{++} + As^{3+} \text{ yields } 2Cu^{+} + As^{5+}$$
(green) (colorless)

FOOTNOTE REFERENCES

1. W. A. Weyl: Series of articles in J. Soc. Glass Tech., Trans., Aug. and Dec. (1943); Aug. and Oct. (1944); Oct. (1945). The authors wish to acknowledge the friendly advice of Dr. Weyl.
2. W. E. S. Turner and W. Weyl: J. Soc. Glass Tech., Trans. 19, 208 (1935).
3. Colors due to colloidal particles (as copper, gold, etc.) are not considered in this investigation.
4. The authors are indebted to Prof. J. O. Krachenbuehl, Dept. of Elec. Eng., for the spectral transmission curves.
5. S. C. Lynd, J. Phys. Chem. 24,437 (1920) calls attention to different causes affecting discoloration and thermoluminescence.
6. Mr. F. O. Brown, Dunbar Glass Corp., first called our attention to these glasses.

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